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THE TERRAPIN SCALE:[1] AN IMPORTANT INSECT ENEMY OF PEACH ORCHARDS.

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INTRODUCTION.

For several years the terrapin scale, *Eulecaniu mnigrofasciatum* Pergande, has been increasing in abundance in certain localities in the eastern United States, and complaints have recently come to the Bureau of Entomology from orchardists in numerous localities within the Appalachian peach belt of severe injury to peaches, and of inability to control the insect with the materials commonly used.

In order to investigate the insect under favorable conditions the Office of Deciduous Fruit Insect Investigations of the Bureau of Entomology maintained a field laboratory during the seasons of 1912 and 1913 at Mont Alto, Pa., which is well within the limits of the badly infested area. The following pages contain a record of the life-history studies made, together with a short historical account of the species. A detailed account is also given of its habits and of the remedies that have been devised for its control.

The author wishes to acknowledge the assistance of Dr. A. L. Quaintance, under whose direction this investigation was conducted, and to thank Messrs. D. M. Wertz and Aaron Newcomer for the use of their orchards and spraying machinery.

[1] *Eulecanium nigrofasciatum* Pergande.

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HISTORY.

The terrapin scale, *Eulecanium nigrofasciatum* Pergande, is a native species which came to the notice of economic entomologists about 1870. Mr. Theodore Pergande, of the Bureau of Entomology, observed it as early as 1872. It was then believed to be the European scale *Lecanium persicae* Fab., an insect of similar habits. The publications prior to 1898, for the most part, refer to it under the latter name. Miss Mary E. Murtfeldt was the first writer to treat of this insect at any length. She observed it in 1893, at Kirkwood, Mo., but did not completely work out its life history. Her observations are recorded in Bulletin 32 [old series] of the Division of Entomology, United States Department of Agriculture (1893), under the name *Lecanium persicae* Fab.

Dr. L. O. Howard treated this species in the Yearbook of the United States Department of Agriculture for 1894 under the name *Lecanium persicae* Modeer, and there figured it for the first time.

Mr. Theodore Pergande became convinced that this lecanium was distinct from *L. persicae* Fab., and described it in Bulletin 18 [new series], Division of Entomology, United States Department of Agriculture (1898), as *Lecanium nigrofasciatum*, new species.

Since about 1898 the terrapin scale has gradually assumed more and more importance as an enemy of the peach, until now it is feared by the peach growers of Maryland and Pennsylvania more than any other species of scale insect. Most of the States east of the one hundredth meridian have mentioned this pest in their entomological publications during the last 10 years. At the present time it appears to be most abundant in portions of Maryland and Pennsylvania.

DISTRIBUTION.

There are no indications that the terrapin scale occurs outside of North America. It is at present, for the most part, confined to the humid area of the Austral Region, but there is danger that it may ultimately invade western peach orchards, especially those in the Austral Zones. This species has been taken in New Mexico and is doubtfully reported from southwestern Colorado, but, so far as known, it does not now occur in the other Western States. It has a slight foothold in Ontario Province, Canada, mostly upon maple. At the present time considerably more than one-half of all the known infestations are found in Pennsylvania and Maryland. (See fig. 1.)

In general this scale has advanced into the region of its principal food plants, having spread through the peach belt of the Eastern United States, and progressed northward beyond this belt by attacking ornamental trees, of which the maples and sycamores seem to be its favorite hosts. It has also extended its range in the Southwest

by attacking the mistletoe, upon which it thrives very well. It will undoubtedly spread considerably beyond its present range by advancing farther into the territory of its chief host plants. Those regions in which the peach, the plum, the maple, the sycamore, and the mistletoe are abundant probably offer suitable conditions for its growth.

ECONOMIC IMPORTANCE.

The terrapin scale, in its range and importance, ranks easily as second among the scale pests of the peach, and while not so prolific and not so injurious as the San Jose scale, *Aspidiotus perniciosus*

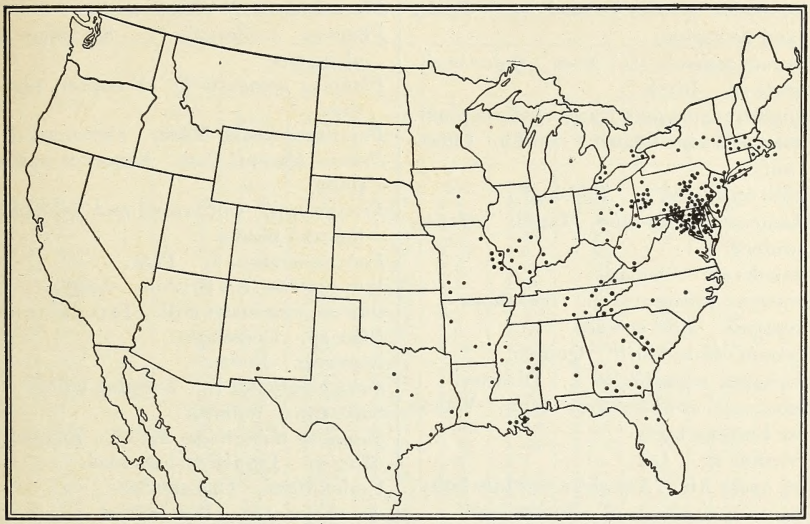


FIG. 1.—Distribution in the United States of the terrapin scale (*Eulecanium nigrofasciatum*). (Original.)

Comstock, it is even more of a nuisance, owing to the difficulty met with in its control.

INJURY.

This insect causes injury first, by sucking the sap from the trees, and second, by covering the fruit, leaves, and branches with a sweet sticky fluid known as honeydew.

The injury to the trees from the loss of sap taken by the scale is considerable in badly infested orchards, but is small in comparison with the damage resulting from the deposit of honeydew. This deposit, while objectionable, would not cause serious injury were it not for a black or sooty fungus which grows abundantly in the honeydew whenever this is present. On trees which are badly infested with the scale the fruit soon becomes covered with a black sticky coat which makes it almost unsalable, as it is nearly all classed as culls and is sold accordingly.

FOOD PLANTS.

Eulecanium nigrofasciatum attacks more than 30 species of plants. It becomes abundant, however, upon only a comparatively few of these. Its preference for its principal food plants is about in the following order: Peach, plum, maple, cherry, sycamore, mistletoe.

The following list includes all of the host plants known to the author:

Acer pseudoplatanus L. Sycamore maple.
Acer saccharinum L. Silver maple.
Acer saccharum Marsh. Sugar or rock maple.
Amygdalus persica L. and var. Peach and nectarine.
Benzoin aestivale (L.) Nees. Spice-bush.
Betula sp. Birch.
Bumelia angustifolia Nutt. Saffron plum.
Castanea dentata (Marsh.) Borkh. Chestnut.
Cercis canadensis L. Red-bud.
Chaenomeles japonica Lindl. Japan quince.
Clematis sp. Clematis.
Crataegus oxyacantha L. Hawthorn.
Crataegus. Most species.
Cydonia oblonga Mill. Quince.
Elaeagnus angustifolia L. Oleaster.
Euonymus atropurpureus Jacq. Wahoo or burning bush.
Fraxinus sp. Ash.
Ilex opaca Ait. American or white holly.
Magnolia virginiana L. Sweet bay.
Melia azedarach L. Wild China-tree.
Morus spp. Mulberry.
Nerium oleander L. Oleander. Rose bay.
Ollea sp. Olive.
Padus sp. Wild cherry.
Phoradendron sp. Mistletoe.
Platanus occidentalis L. Sycamore or plane-tree.
Platanus orientalis L. European plane-tree.
Populus deltoides Marsh. Cottonwood.
Prunus sinconii Carr. Simon or apricot plum.
Prunus spp. Cultivated and wild cherries and plums.
Pyrus communis L. Pear.
Pyrus malus (L.) Britton. Apple.
Quercus virginiana Mill. Live oak.
Ribes sp. Gooseberry.
Rosa spp. Roses.
Salix babylonica L. Weeping willow.
Salix spp. Willows.
Sapindus marginatus Willd. Soapberry.
Tilia sp. Linden or basswood.
Umbelliferæ. One species.
Vaccinium spp. Blueberries.
Vitis vinifera L. European grape.
Vitis spp.

LIFE HISTORY.

MATURING OF FEMALES IN SPRING.

Hibernation is terminated by weather conditions. The conditions that cause the peach buds to open also bring this lecanium to the end of hibernation. At Mont Alto, Pa., in 1913, hibernation ended about April 1, at which time many blossoms were ready to burst. From April 1 to May 1 growth was rapid. From May 1 to May 16 it was comparatively slow. At the latter date the advanced females reached their maximum size, which they retained until the period of reproduction was nearly over. All the females had reached maturity by June 10. Table I shows the minimum, maximum, and average sizes of 414 specimens measured during the spring development and the reproduction periods of 1912 and 1913 at Mont Alto, Pa.

This material was taken from vigorous trees. Twigs containing about 200 specimens were cut to secure material for each measurement. To overcome the natural variation in size the 50 largest specimens were removed from the twigs and the largest of these taken each time for measuring. These measurements show the following maxima:

Length, May 16, 1912..... 3.7 mm.
Width, May 30, 1912..... 3.35 mm.
Height, May 24, 1913..... 1.60 mm.

TABLE I.—*Measurements showing growth of 414 females of the terrapin scale during the spring development, Mont Alto, Pa., 1912 and 1913.*

Date.	Number of specimens.	Length.			Width.			Height.		
		Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.
		Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
Feb. 24, 1913	25	1.80	2.375	2.076	1.8	2.275	2.030	0.725	1.10	0.908
Mar. 28, 1913	20	1.726	2.053	1.891	1.633	2.146	1.758	.65	.85	.741
Apr. 8, 1913	20	1.825	2.31	2.114	1.87	2.255	2.060	.73	.975	.854
Apr. 10, 1912	10	1.81	2.2	1.995	1.75	2.2	1.905	.8	1.15	.949
Apr. 11, 1912	3	1.85	1.9	1.88	1.8	1.9	1.833			
Apr. 16, 1912	13	1.6	2.55	1.926	1.5	2.35	1.828			
Apr. 17, 1913	20	1.87	2.53	2.195	1.842	2.365	2.037	.865	1.1	.953
Apr. 19, 1912	10	2.05	2.7	2.372	2.1	2.375	2.302	.825	1.00	.922
Apr. 22, 1912	10	1.7	2.3	2.057	1.6	2.25	1.900			
Apr. 23, 1913	20	2.24	2.98	2.576	1.82	2.613	2.298	.85	1.225	.995
Apr. 26, 1912	10	1.975	2.925	2.314	1.725	2.625	2.200			
Apr. 28, 1913	20	2.613	3.427	2.866	2.24	3.033	2.566	.925	1.275	1.118
Apr. 30, 1913	20	2.706	3.042	2.94	2.473	2.94	2.721	1.00	1.3	1.165
May 6, 1912	6	2.5	2.975	2.666	2.3	2.675	2.458	1.00	1.25	1.437
May 7, 1913	20	2.893	3.22	3.024	2.501	2.893	2.639	1.2	1.50	1.343
May 10, 1913	20	2.8	3.266	3.021	2.52	2.893	2.674	1.05	1.50	1.317
May 16, 1912	10	2.65	3.7	3.127	2.65	3.3	2.94			
May 16, 1913	20	2.94	3.621	3.204	2.52	3.173	2.951	1.225	1.19	1.365
May 23, 1913	20	2.8	3.38	3.046	2.61	3.22	2.851	1.15	1.475	1.333
May 24, 1913	20	2.8	3.36	3.170	2.706	3.266	2.950	1.225	1.60	1.435
May 30, 1912	7	2.5	3.525	3.217	2.7	3.35	3.067	1.07	1.43	1.352
May 31, 1913	20	2.983	3.453	3.177	2.613	2.986	2.844	1.20	1.49	1.319
June 3, 1913	20	2.893	3.593	3.113	2.613	3.08	2.811	1.20	1.55	1.392
June 5, 1912	2	3.05	3.5	3.275	2.5	3.1	2.8	1.325	1.375	1.35
June 7, 1913	20	2.8	3.36	3.102	2.66	3.22	2.885	1.275	1.525	1.383
June 20, 1913	20	2.52	3.173	2.947	2.426	2.986	2.717	1.22	1.525	1.384
June 28, 1912	8	2.6	3.05	2.887	2.7	3.30	2.85	1.075	1.5	1.282
Total	414									

It is doubtful whether individuals ever are large enough to have all the above measurements, since excessive size in one dimension is accompanied by a smaller size in the other dimensions.

The date of greatest average measurements of the same 414 specimens are:

	Mm.
May 30, 1912, length (7 specimens)	3.217
May 30, 1912, width (7 specimens)	3.067
May 6, 1912, height (6 specimens)	1.437

It is evident from these data that the females reach their maximum size between the middle of May and the end of the first week in June.

THE EMBRYO.

The terrapin scale is viviparous. Authors making reference in literature to the eggs of this insect undoubtedly referred to the embryos, which probably were mistaken for eggs. Undeveloped eggs are present in some specimens in the fall before hibernation. Dissections made September 9, 1913, showed a pair of very small racemose ovaries containing a few undeveloped eggs located to the right and left of the alimentary canal, and a small, globular, brown-colored receptaculum seminis attached to the vagina. Dr. Quaintance has observed eggs in hibernating females from Winchester, Va., as early as January 19. The writer has taken rudimentary eggs at various times during the hibernating period. With the renewal of growth in the spring there is a rapid increase in both the number and size of the eggs. The average size of four embryos at birth was as follows: Length, 0.3437 mm.; width, 0.1625 mm.

The data in Table II were taken from the largest embryos obtained at each dissection. Some of these were nearly full size by May 16, although it was not until the first week in June that the eyespots and segments became prominent.

TABLE II.—*Measurements of developing embryos of the terrapin scale, taken by dissection, 1913.*

Date.	Number of specimens.	Average length.	Average diameter.	Locality.
		Mm.	*Mm.*	
May 10	5	0.2986	0.1754	Mont Alto, Pa.
16	4	.3343	.1781	Do.
17	5	.32	.184	Do.
23	5	.344	.173	Do.
27	5	.346	.1625	Midvale, Pa.
June 28[1]	4	.3437	.1625	Mont Alto, Pa.

[1] Measured at birth.

The ovaries remain active and continue to produce eggs as long as nutriment is supplied to them. They are among the last organs of the scale to disintegrate.

Table III gives data from dissections during the spring of 1912 and 1913. These counts show that most of the embryos are formed before the end of May. The greatest number found was 881 on June 4, 1913, and the ovaries of the parent scale were still active. It is evident from this that vigorous females may produce as many as 900 embryos. The oldest embryos are far advanced by June 6, and they are mature by June 15, at which time the eyes, the appendages, and the abdominal segments were clearly seen through the membrane.

TABLE III.—*Rudimentary eggs and embryos from developing females of the terrapin scale, taken at Mont Alto, Pa., during the seasons of 1912 and 1913.*

Date of dissection.	Females dissected on given dates.	Large embryos.	Rudimentary eggs.	Date of dissection.	Females dissected on given dates.	Large embryos.	Rudimentary eggs.
1912.				1912.			
May 27	1	604	Many.	June 15	1	747	Few.
May 28	1	271	Do.	Do	2	611	Many.
Do	2	297	Do.				
May 29	1	349	Do.	1913.			
Do	2	386	Do.	May 16	1	632	Do.
May 30	1	625	Do.	June 4	1	881	Do.
Do	2	463	Do.	June 7	1	734	Do.
Do	3	573	Do.	Do	2	758	Do.
June 5	1	362	Do.	Do	3	689	Do.
Do	2	696	Do.	Do	4	785	Do.
June 6	1	824	Few.	Do	5	663	Do.
June 7	1	684	Do.	Do	6	598	Do.

The data given in Table IV show the number of embryos produced by 13 normal scales during the season of 1912. These data were obtained by isolating the individual scales with tree tanglefoot and taking the daily emergence. When these scales loosened at the end of their reproductive periods they were removed and dissected. The average number of embryos per scale was 406.34. In this experiment approximately 50 per cent of the embryos that formed appeared as migrating larvæ.

TABLE IV.—*Record of progeny and embryos from 13 parent terrapin scales, season of 1912, at Mont Alto, Pa.*

No.	Date of dissection.	Number of embryos, emerging as larvæ.	Embryos taken by dissection.	Total embryos.	Condition of embryos removed by dissection.	Condition of scale when taken for dissection.
	1912.					
1	July 12	142	451	593	One-third dead	Loose and exhausted.
2	15	189	60	249	Mostly dead	Do.
3	3	214	204	418	do	Do.
4	15	245	218	463	do	Nearly exhausted.
5	15	189	192	381	do	Exhausted.
6	10	137	37	174	All dead	Do.
7	15	119	150	269	do	Do.
8	12	303	326	629	One-fourth dead	Black; nearly exhausted.
9	15	220	195	415	Mostly dead	Nearly exhausted.
10	15	168	138	306	All dead	Exhausted.
11	15	187	22	209	do	Do.
12	15	349	193	542	do	Do.
13	15	291	343	634	do	Do.
Total		2,753	2,529	5,282		

It will be noticed from Table IV that most of these scales were removed for dissection upon July 15. These scales were among the most advanced in the orchard. Their exhaustion in the middle of July does not therefore represent the end of reproduction in the orchard, which came much later.

BIRTH OF THE TERRAPIN SCALE, AS OBSERVED AT MONT ALTO, PA., IN 1913.

The following data were obtained by observing 50 scales which gave birth to 3,000 young during the period of 4 days, June 22 to June 26, 1913:

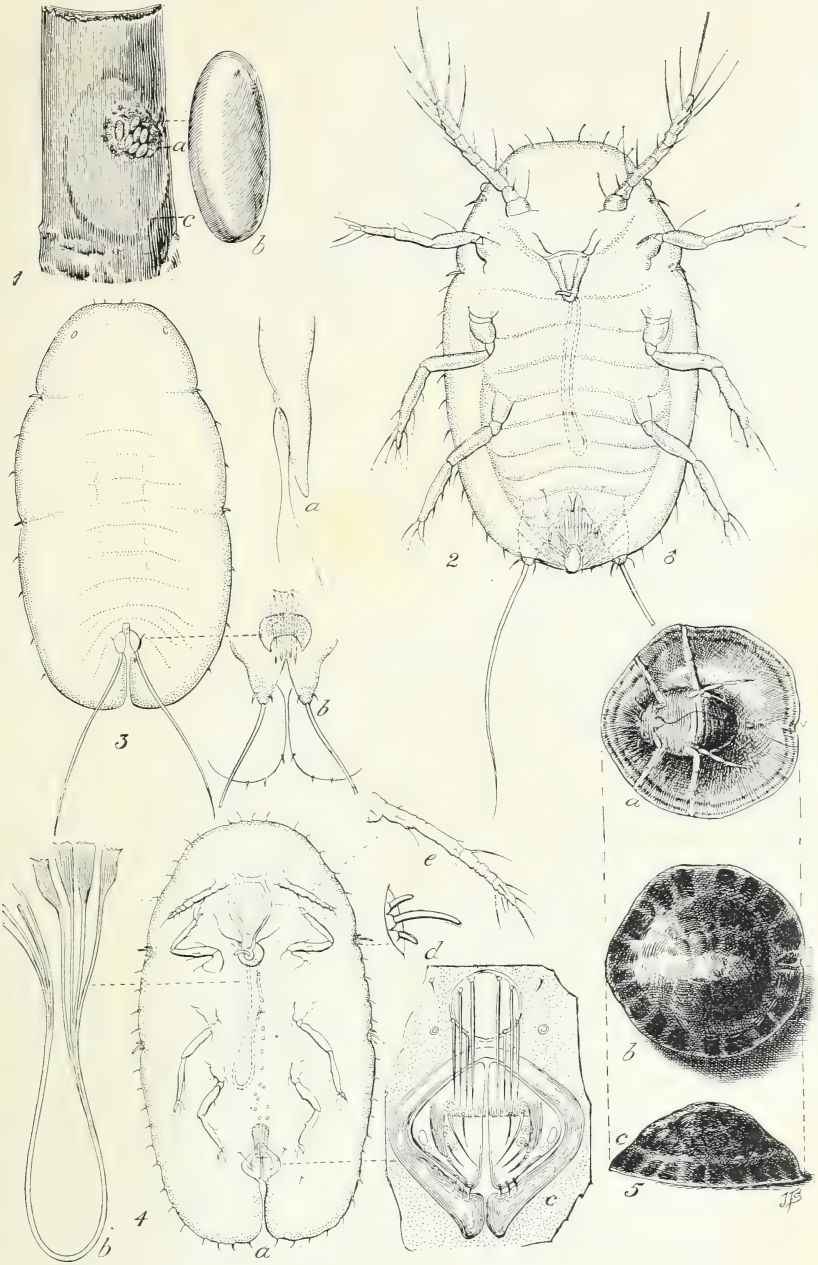
The young are brought forth as embryos, usually inside of a sac or amniotic membrane. The vaginal passage of the mother offers considerable resistance to the passage of the first young of the season, as they are very turgid or swollen, and the amniotic sac is nearly always ruptured, allowing the embryo to escape. This is the only time when they are born free, as later in the season the embryonic sac comes through unbroken. Toward the end of the season the larvæ, after birth, may remain as long as 8 minutes in the embryonic membrane, but the time is seldom more than 4 minutes. The embryos have an average length of 0.36 mm., and a transverse diameter averaging 0.18 mm. (Pl. I, fig. 1, *b*.)

The structure of the larva shows through the amniotic membrane. The antennæ are folded downward and lie parallel along the ventral surface. The proboscis lies between the antennæ and extends along the midventral line for three-fourths of the length of the body. The legs lie alongside the antennæ and extend beyond them to near the posterior end of the body. The major apical setæ and the anal plates are folded forward upon the ventral surface of the body. The eyes show prominently through the membrane. The sides of the body are rolled slightly inward, so as nearly to enfold the ventral appendages. When the embryonic membrane bursts the young appears as a wet, flat larva, which remains motionless for a few minutes, during which the body unfolds and the appendages assume their normal position. The cast membranes of the numerous progeny remain and form a deposit on the floor of the brood chamber. (Pl. I, fig. 1, *a*.) Twenty minutes after birth the larvæ have assumed their characteristic flatness and are moving about in the brood chamber, where they remain usually until the following day, or even longer if unfavorable weather conditions prevail.

Observations of birth are difficult. The displacement necessary for observing this operation loosens the feeding tube and so deprives the parent of the needed nutriment. It is, therefore, impractical to make observations covering an extended interval.

At the beginning of reproduction the time between births may be as short as 2 minutes. As the exhaustion of the parent increases the interval between births becomes longer, until by the thirtieth day birth has practically stopped.

Table V gives birth data for 7 larvæ from well-exhausted parents, under favorable conditions. It shows an average interval between births of 8.5 minutes and the average time per birth as 2.43 minutes. These birth data can be taken as a good average for the major part



THE TERRAPIN SCALE.

FIG. 1.—Embryos and larvæ as disclosed by removing a female near the end of reproduction: *a*, Embryos in situ; *b*, embryo enlarged; *c*, area covered by the scale. (Enlarged.) FIG. 2.—First-instar male at the leafward migration. (Greatly enlarged.) FIG. 3.—Leaf-attached larva near the end of the first instar: *a*, Lateral view of the caudal extremity; *b*, enlargement of the anal plates. (Greatly enlarged.) FIG. 4.—Female at twigward migration (greatly enlarged): *a*, Anal cleft (greatly enlarged); *b*, enlarged mouth parts; *c*, ventral view of the anal plates; *d*, spiracular spines, more enlarged; *e*, antenna, more enlarged. FIG. 5.—The mature female: *a*, Ventral view; *b*, dorsal view; *c*, lateral view. (Enlarged.) (Original.)

of the reproductive period. The averages are too long, however, for the first 3 or 4 days of reproduction.

TABLE V.—*Birth data of 7 larvæ of the terrapin scale under favorable conditions, Mont Alto, Pa.*

Females.	Number of larvæ.	Temperature at start.	Embryo at orifice.	Birth completed.	Time required.	Interval between births.	Date.	Degree of exhaustion of the female.	Atmospheric conditions.
		° F.	a. m.	a. m.	Minutes.	Minutes.	1913.	Per cent.	
I	1	75	7.14	7.17	3		June 24	70	Favorable.
I	2	75	7.24	7.28	4	11	...do.....	70	Do.
I	3	75	7.35	7.36	1	8	...do.....	70	Do.
II	1	75	7.16	7.18	2		...do.....	70	Do.
II	2	75	7.24	7.27	3	9	...do.....	70	Do.
II	3	75	7.31	7.33	2	6	...do.....	70	Do.
III	1	75	8.07	8.09	2		...do.....	70	Do.
Average		75			2.43	8.5			

Table VI gives data for 7 larvæ from two well-exhausted parents under rather unfavorable conditions. These data show an average interval between births of 13.87 minutes. They also show that the interval varies widely in the case of different individuals.

TABLE VI.—*Birth data for the terrapin scale under unfavorable conditions, Mont Alto, Pa., 1913.*

Female.	Number of larvæ.	Temperature at start.	Time of birth.	Interval between births.	Date.	Degree of exhaustion.	Weather conditions.
		° F.	a. m.	Minutes.	1913.	Per cent.	
I	1	74	7.37		June 13	70	Unfavorable.
	2	74	7.43	6	...do.....	70	Do.
	3	75	7.50	7	...do.....	70	Do.
	4	76	8.05	15	...do.....	70	Do.
Average for first female		75		9.3			
II	1	76	8.03		June 13	90	Do.
	2	76	8.24	20.6	...do.....	90	Do.
	3	76	8.45	20.75	...do.....	90	Do.
Average for second female		76		20.67			
Average for both females				13.87			

THE YOUNG LARVÆ IN THE BROOD CHAMBER.

In the orchard the larvæ appear in the brood chambers from 1 to 3 days before any of them emerge. During the time of maximum emergence most of the larvæ remain in the brood chamber only until the day following birth. If larvæ are removed from the brood chamber by overturning the scales they migrate at once to the leaves. Even those that have been born but a few hours do this. The maximum time during which they can remain in the brood chamber depends upon their ability to live without food. Experiments indicate that 4 days is the maximum limit of life for unemerged larvæ.

After periods of unfavorable weather lasting from 3 to 5 days dead young are always found in the brood chambers. Unfavorable weather up to 3 days duration does not seem to have an unfavorable effect upon the unemerged larvæ.

EMERGENCE.

Unless weather conditions interfere, the emergence starts upon the second day after the young appear in the brood chambers.

In 1912 a scattered emergence started in the orchard at Mont Alto, Pa., on June 8, with the first young in the brood chambers on June 6. These specimens showed the regular two-day interval between birth and emergence. The regular emergence did not start until a week later.

Emergence from 26 isolated females started June 16, and gave its daily maximum on June 18. Upon June 25, 50 per cent had emerged, and 75 per cent had emerged July 1. Emergence from these scales ceased July 17, after 4,273 had emerged. Twenty-nine specimens in all were isolated at the start of the foregoing experiment. Data from all these are included in Table VII. Specimens numbered 12, 16, and 23 were so manifestly abnormal that they were omitted in calculating the foregoing percentages.

TABLE VII.—*Record of 29 isolated females of the terrapin scale during the emergence period of 1912, at Mont Alto, Pa.*

No.	Total emergence.	Last larva emerged.	Scale loose.	Scale dropped.	Scale taken.	Embryos by dissection.	Number dead embryos.
1	142	July 8	July 12	.....	July 12	451	One-third.
2	121	July 3	July 4	.....	July 5	0	All.
3	189	July 9	.....	.....	July 15	60	Most.
4	214	July 3	.....	.....	July 3	204	Do.
5	245	July 15	.....	.....	July 15	218	Do.
6	189	July 13	July 8	.....	...do.....	192	Do.
7	152	June 26	.....	June 26	.....	.....	
8	137	July 7	July 10	.....	July 10	37	Do.
9	119	July 15	.....	.....	July 15	150	All.
10	143	June 27	.....	June 30	.....	.....	
11	303	July 7	July 12	.....	July 12	326	One-fourth.
12	3	June 21	.....	June 24	.....	.....	
13	146	July 2	.....	July 3	.....	.....	
14	88	July 8	July 11	.....	July 11	8	All.
15	220	July 12	.....	.....	July 15	195	Most.
16	11	June 24	.....	July 7	.....	.....	
17	124	July 15	.....	.....	July 15	97	All.
18	168	...do.....	.....	.....	...do.....	138	Do.
19	71	June 24	.....	June 25	.....	.....	
20	187	July 15	.....	.....	July 15	22	Do.
21	349	July 12	.....	.....	...do.....	193	Do.
22	45	July 15	.....	.....	...do.....	24	Do.
23 [1]	1	June 22	.....	June 25	.....	.....	
24	42	July 8	July 8	.....	July 8	145	Do.
25	291	July 6	July 6	.....	July 6	343	Do.
26	144	July 11	.....	July 12	.....	.....	
27	151	July 6	July 11	.....	July 11	359	Most.
28	153	July 15	.....	.....	July 15	148	Do.
29	125	July 8	July 11	.....	July 11	73	Do.
Total	4,273	.....	.....	.....	.....	3,383	

[1] Larva of *Hyperaspis binotata* emerged June 24.

Total embryos, 7,656.

Table VII gives, in summary, the history of the isolated scales used in 1912. It shows the ratio between the number of emerged larvæ and the total number of embryos produced, but it does not show the date of exhaustion of all the scales.

Table VIII gives the detailed emergence of larvæ for 29 isolated females from June 16 to July 15, 1912. At the latter date the scales were nearly all exhausted and 18 of them had dropped. Only 9 were able to produce young at the time of removal. The total number emerging was 4,273. Scale No. 21 gave 349, the highest number of larvæ produced by any of these scales.

TABLE VIII.—*Daily emergence of larvæ from the 29 isolated females of the terrapin scale in Table VII, Mont Alto, Pa., 1912.*

No.	June, 1912.															
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1			1	37		4				3	1	3	1			
2			1			21		14	1	6	10	20	14	17	1	
3						4		7	6	28	8	20	17	26	1	
4				33		33	3	20	25	4	3	9	11	26	24	8
5				22		21	6	16	9	12	7	30	14	16	12	3
6			1	2		8	3	24	18	17	10	12	13	29	3	
7 [1]		2	4	37		34	7	2	10	44	6	6				
8		3	4	44		7	4	13	13	5	5	8	6	18	1	
9						8	5	4	8	7	15	20	6	12	1	
10				62		30	12	6	5	4	7	14	3			
11		2	3	110		45	18	15	10	9	12	24	9	24	1	
12						1	2									
13			2	50		46	9	10		16	3	5	3	1		
14				5		9	3		11	20	12	20	5			
15						39	11	16		9	8	14	14		3	
16			1					2	4	4						
17							1		4	4	8	20	13		10	2
18			1	6			7	8	11	11	15	26	10	21	2	
19						15	13	11	5	27						
20			1				4	8	3	9	6	12	6	14	2	
21		2	4	80		48	22	26	19	9	18	20	13	14		
22										1			1			
23 [2]								1								
24 [3]								4		8	1	2	8			
25 [4]			1	32	2	32	11	39	19	21	15	20	13	24	10	2
26							1		1		1	2	7	4	7	
27				14		16	8	15	5	9	7	15	25			
28							14		15	6	8	16	11	19	3	1
29											8	30	6	30	10	5
Total		9	24	534	2	421	164	261	202	296	194	368	229	295	91	21

[1] Dropped June 26.
[2] *Hyperaspis binotata* larva emerged June 24; scale dropped June 25.
[3] Loose and removed for dissection July 8.
[4] Loose and removed for dissection July 6.

TABLE VIII.—*Daily emergency of larvæ from the 29 isolated females of the terrapin scale in Table VII, Mont Alto, Pa., 1912*—Continued.

No.	July, 1912.															Total.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
1	30	14	11	9	.....	19	3	6	.....	.....	.....	.....	.....	.....	.....	142
2	2	10	4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	121
3	33	14	2	2	1	1	.....	11	3	.....	.....	.....	.....	.....	5	189
4	7	1	7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	214
5	21	3	6	10	.....	8	1	11	3	5	.....	.....	.....	.....	8	245
6	23	2	5	3	.....	7	3	4	1	.....	.....	.....	1	.....	.....	189
7 [1]	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	152
8	.....	4	.....	.....	.....	.....	2	.....	.....	.....	.....	.....	.....	.....	.....	137
9	9	2	2	3	.....	8	.....	7	.....	1	.....	.....	.....	.....	1	119
10	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	143
11	6	5	.....	2	.....	6	2	.....	.....	.....	.....	.....	.....	.....	.....	303
12	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	3
13	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	146
14	.....	2	.....	.....	.....	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	88
15	43	14	5	10	.....	9	3	9	4	2	4	2	.....	.....	1	220
16	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	11
17	28	6	5	2	.....	3	5	9	.....	1	1	.....	.....	.....	2	124
18	17	7	4	2	.....	7	1	3	2	.....	2	.....	2	.....	3	168
19	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	71
20	36	17	3	9	.....	24	5	7	7	4	3	4	.....	.....	3	187
21	28	11	5	5	1	3	.....	11	6	.....	3	1	.....	.....	.....	349
22	2	3	.....	3	.....	9	11	6	4	.....	2	.....	.....	.....	3	45
23 [2]	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1
24 [3]	2	.....	.....	.....	.....	.....	.....	17	.....	.....	.....	.....	.....	.....	.....	42
25 [4]	13	4	2	4	19	6	.....	.....	.....	.....	.....	.....	.....	.....	.....	292
26	31	12	5	15	.....	13	9	21	8	5	2	.....	.....	.....	.....	144
27	23	3	4	4	.....	3	.....	.....	.....	.....	.....	.....	.....	.....	.....	151
28	7	14	3	2	.....	6	3	7	4	2	3	4	.....	.....	5	153
29	19	6	4	3	.....	2	.....	2	.....	.....	.....	.....	.....	.....	.....	125
Total	380	155	77	88	21	134	48	132	42	20	21	11	3	.....	31	4,273

[1] Dropped June 26.
[2] *Hyperaspis binotata* larva emerged June 24; scale dropped June 25.
[3] Loose and removed for dissection July 8.
[4] Loose and removed for dissection July 6.

The weather was abnormal during the emergence period of 1912. It was very cold, with a daily maximum below 70° F. from June 13 to 15, inclusive. June 19 was rainy and cold, with the daily maximum below 60° F. The daily maximum did not go above 70° until June 22, when it rained. From June 24 to 28, inclusive, the weather was favorable, except for local showers on June 25 and 27. June 29 and 30 were unfavorable, due to a cold rain and no sun. July 5 also was a rainy day. The only favorable weather was from July 6 to 11, inclusive, but it was too late to have an appreciable effect.

The dotted curve on the following emergence graph, figure 2, shows clearly the effect of these weather conditions. The solid line shows the curve as it would probably be in favorable weather.

During 1913 a few larvæ appeared in the brood chambers at Mont Alto, Pa., on June 11. The larvæ were quite abundant in the brood chambers on June 12, and emergence started June 13. Thus the interval between first birth and first emergence was 2 days. The emergence from the isolated scales also started June 13 and the maximum daily emergence was June 18. Fifty per cent and the 75

per cent of emergence came upon June 23 and June 30, respectively. Emergence ceased September 30, after 12,336 larvæ had emerged.

Table IX gives an individual record of the scales observed in 1913, showing the date of exhaustion. It also shows the effect of the

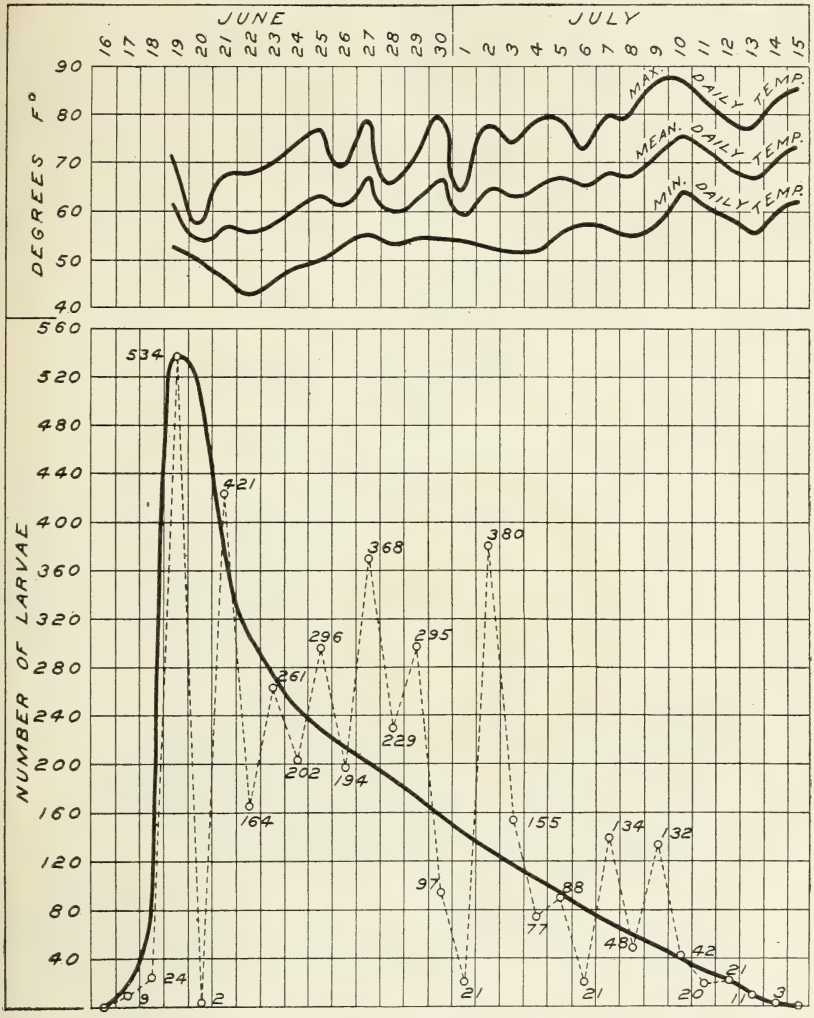


FIG. 2.—Emergence curve for the first 28 days of emergence of the terrapin scale, Mont Alto, Pa., 1912. (Original.)

attack of Hymenoptera and the effect of the predacious beetle *Hyperaspis binotata* Say, but does not show the total number of embryos.

TABLE IX.—*The emergence from 41 isolated females of the terrapin scale during the emergence period of 1913, Mont Alto, Pa.*

No.	Total larvæ.	Last larva emerged.	Parent scale turned black.	Knocked off by accident.	Scale loosened.	Scale dropped.	Scale dead.
1	204	July 14	.....	.....	.....	.....	July 14
2	76	July 1	.....	.....	.....	July 21	July 21
3	494	Aug. 7	.....	Aug. 27	.....	.....	.....
4	206	July 4	.....	.....	July 4	July 4	July 11
5	209	June 29	.....	.....	.....	July 10	June 30
6	233	Aug. 30	Sept. 5	.....	.....	Sept. 30	Sept. 1
7	421	Aug. 26	...do....	.....	.....	Sept. 2	Aug. 28
8	708	Sept. 19	.....	.....	.....	Sept. 30	Sept. 20
9	458	July 20	.....	.....	.....	Aug. 15	July 2
10	796	Aug. 30	.....	Sept. 2	Sept. 1	Sept. 2	.....
11 [1]	245	June 30	.....	.....	.....	July 31	July 1
12	663	Sept. 30	.....	.....	.....	Oct. 11	Oct. 11
13 [2]	221	July 7	.....	.....	.....	Aug. 1	July 8
14	165	June 28	.....	.....	June 22	June 28	June 28
15	53	June 22	.....	June 22	...do....	.....	.....
16 [3]	387	July 21	.....	.....	.....	.....	Aug. 7
17 [4]	389	July 7	.....	.....	.....	Aug. 1	Aug. 1
18 [5]	192	July 2	.....	.....	.....	July 18	July 18
19	174	June 29	.....	.....	.....	July 1	July 1
20 [6 7]	94	June 24	June 15	.....	.....	July 21	June 22
21 [8]	394	July 5	.....	.....	.....	July 18	July 18
22	130	...do....	.....	.....	.....	July 11	July 6
23	240	July 6	.....	.....	.....	July 18	July 7
24	114	June 20	.....	June 22	.....	.....	.....
25	9	June 19	.....	.....	June 21	June 22	June 22
26	389	July 10	.....	.....	.....	July 11	July 11
27	267	June 28	.....	.....	.....	June 29	June 29
28	654	Aug. 18	.....	Aug. 23	.....	.....	.....
29 [9]	472	Aug. 14	.....	.....	.....	.....	Aug. 27
30	309	Aug. 1	.....	.....	.....	Oct. 11	Aug. 2
31 [10]	196	July 3	.....	.....	.....	Aug. 18	Aug. 1
32	42	June 29	.....	.....	.....	July 1	July 1
33	76	July 2	.....	.....	.....	.....	July 3
34	121	June 23	.....	June 23	.....	.....	.....
35	98	June 28	.....	.....	.....	June 28	June 28
36	464	Aug. 7	.....	.....	.....	.....	Aug. 27
37	373	July 14	.....	.....	.....	.....	July 15
38	433	July 26	.....	.....	.....	Aug. 11	Aug. 11
39	391	July 6	.....	.....	.....	Aug. 18	July 17
40	657	Sept. 19	.....	.....	.....	.....	Sept. 20
41	119	July 21	.....	.....	.....	Aug. 23	July 22
Total	12,336						

[1] First instar *Hyperaspis binotata* emerged from this scale July 1.
[2] First instar *Hyperaspis binotata* emerged from this scale July 14.
[3] One hymenopterous parasite (*Coccophagus* sp.) emerged from this scale Aug. 7.
[4] Two hymenopterous parasites (*Coccophagus* sp.) emerged from this scale July 16.
[5] Seven hymenopterous parasites (*Coccophagus* sp.) emerged from this scale July 13.
[6] First instar *Hyperaspis binotata* emerged from this scale July 5.
[7] Three hymenopterous parasites (*Coccophagus* sp.) emerged from this scale July 13.
[8] Second instar *Hyperaspis binotata* emerged from this scale July 18.
[9] First instar *Hyperaspis binotata* emerged from this scale July 18.
[10] First instar *Hyperaspis binotata* emerged from this scale June 30.

The emergence started June 13 with 18 larvæ; the maximum daily emergence occurred upon June 18, when 1,229 larvæ emerged. This was 5 days after emergence had started. The first half of the brood (6,168 larvæ) completed its emergence upon June 23. This was the tenth day of emergence. Seventy-five per cent of the brood (9,250 larvæ) had emerged by June 30. This was upon the seventeenth day of emergence. The daily emergence was not taken for the entire period of 1913, but data for the first 22 days, which cover slightly more than three-fourths of the total emergence, are given in Table X.

Table XI supplements Table X. It carries the emergence through the entire period by weeks. It also gives the date of the end of emergence for each of the parent scales.

TABLE X.—*Daily emergence from the 41 isolated females of the terrapin scale in Table IX, during the first 22 days of emergence, Mont Alto, Pa., 1913.*

No.	June.																		July.				Total.
	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	
1	.....	.....	.....	30	8	15	12	11	18	4	27	5	16	5	12	8	9	4	4	5	.....	.....	193
2	1	.....	.....	5	.....	1	.....	4	2	2	1	14	10	3	11	5	10	.....	1	.....	.....	.....	70
3	.....	1	2	1	20	53	17	30	45	9	71	11	31	8	18	10	8	11	11	8	3	3	371
4	.....	.....	1	.....	10	12	13	40	28	10	15	7	5	5	12	10	13	4	3	11	3	2	204
5	.....	4	2	11	9	20	18	10	56	18	8	3	1	9	20	11	9	.....	.....	.....	.....	.....	209
6	.....	.....	.....	1	7	7	6	14	21	2	28	7	1	3	6	.....	4	6	5	4	7	7	136
7	.....	.....	3	14	27	40	28	39	38	28	2	4	22	3	7	4	9	3	2	15	5	4	297
8	2	.....	8	25	20	36	26	31	37	10	17	8	39	9	30	6	22	18	18	12	2	2	378
9	2	.....	22	22	50	71	24	33	53	45	13	3	25	5	12	11	2	9	8	7	4	2	423
10	.....	.....	3	15	15	27	20	28	43	30	10	16	22	3	13	40	9	48	17	9	3	2	373
11	.....	1	3	2	25	25	10	16	51	20	25	5	35	5	25	1	.....	1	.....	.....	.....	.....	250
12	.....	1	31	16	50	60	18	28	41	15	18	9	30	6	10	12	39	3	2	3	.....	.....	392
13	9	23	18	25	24	40	7	30	4	9	3	6	7	.....	1	7	4	.....	.....	.....	2	.....	219
14	2	4	2	2	20	33	18	37	17	15	6	.....	6	1	1	1	.....	.....	.....	.....	.....	.....	165
15	.....	.....	.....	16	10	12	1	11	2	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	53
16	.....	.....	.....	20	15	29	24	37	60	27	30	4	25	6	30	10	11	3	3	5	5	4	348
17	.....	.....	.....	7	21	50	18	42	68	9	73	11	38	2	12	9	7	9	9	.....	2	.....	387
18	.....	1	12	16	10	22	4	7	15	9	50	3	12	.....	5	23	2	.....	.....	1	.....	.....	192
19	.....	.....	.....	1	8	18	5	2	20	.....	7	2	6	20	47	27	9	.....	.....	.....	.....	.....	172
20	.....	.....	.....	6	9	18	4	7	49	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	94
21	.....	.....	8	.....	.....	5	46	36	57	25	12	30	59	.....	30	29	18	11	11	14	4	3	398
22	.....	.....	14	13	12	13	10	11	10	10	5	5	7	.....	3	.....	.....	.....	.....	8	4	3	128
23	.....	.....	.....	2	26	40	15	23	19	18	6	17	27	4	120	5	4	4	3	8	5	2	348
24	2	6	14	14	7	30	4	27	10	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	114
25	.....	.....	.....	2	1	2	4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	9
26	.....	1	1	12	25	83	26	63	26	6	7	19	25	7	30	10	5	7	7	7	6	2	375
27	.....	1	.....	.....	16	28	31	40	50	2	2	50	26	6	12	3	.....	.....	.....	.....	.....	.....	267
28	.....	.....	.....	12	14	50	38	40	38	16	8	61	7	14	68	20	21	9	9	4	8	4	441
29	.....	.....	.....	.....	9	20	15	22	42	20	14	69	17	6	20	28	5	1	1	.....	3	2	294
30	.....	.....	1	6	4	20	20	32	50	20	20	32	29	7	30	18	3	6	5	2	1	1	307
31	.....	.....	.....	.....	10	27	16	29	28	2	3	30	15	7	25	3	4	.....	.....	.....	1	.....	200
32	.....	.....	.....	.....	.....	4	.....	7	4	.....	1	20	.....	.....	4	1	1	.....	.....	.....	.....	.....	42
33	.....	.....	.....	.....	.....	.....	.....	12	.....	15	20	.....	.....	.....	8	9	10	.....	.....	2	.....	.....	76
34	.....	.....	.....	4	7	30	30	38	.....	6	6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	121
35	.....	.....	.....	.....	.....	4	4	9	20	10	4	13	15	3	7	4	.....	.....	.....	.....	.....	.....	93
36	.....	.....	.....	.....	17	30	20	20	15	7	5	26	16	6	21	25	30	9	11	10	11	5	284
37	.....	.....	.....	10	20	70	38	40	25	75	11	21	11	4	12	4	15	1	2	1	1	.....	361
38	.....	.....	.....	12	20	50	20	52	35	25	15	44	28	10	25	4	10	2	6	4	2	2	366
39	.....	.....	.....	.....	.....	79	30	31	30	21	15	10	20	3	20	13	12	2	3	3	.....	.....	292
40	.....	.....	.....	.....	.....	35	35	36	40	21	20	43	16	2	16	3	3	6	6	6	1	.....	289
41	.....	.....	.....	.....	.....	20	20	16	15	5	2	10	7	4	7	2	2	1	.....	.....	3	1	115
Total	18	43	145	322	546	1,229	695	1,041	1,182	567	580	619	656	176	730	376	310	178	147	151	86	51	9,846

TABLE XI.—*Weekly emergence from the 41 isolated females of the terrapin scale in Table IX, Mont Alto, Pa.*

No.	Total larvæ.	June 13–19.	June 20–26.	June 27–July 3.	July 4–10.	July 11–17.	July 18–24.	July 25–31.	Aug. 1–7.	Aug. 8–14.	Aug. 15–21.	Aug. 22–28.	Aug. 29–Sept. 4.	Sept. 5–11.	Sept. 12–18.	Sept. 19–25.	Sept. 26–Oct. 2.	Emergence ended.
1	204	65	86	42	0	11												July 14
2	76	7	36	27	0	0	6											July 1
3	494	94	205	69	18	25	20	32	31									Aug. 7
4	206	36	110	56	4													July 4
5	209	64	105	40														June 29
6	233	21	76	32	18	26	29	20	6	3	0	1	1					Aug. 30
7	421	106	136	45	37	50	40	3	1	2		1						Aug. 26
8	708	117	151	108	20	40	34	51	21	50	48	13	41	12	1	1		Sept. 19
9	458	191	177	55	22	12	1											July 21
10	796	80	152	109	31	33	67	86	79	50	77	21	11					Aug. 30
11	245	66	157	22														June 30
12	663	170	147	69	13	33	61	56	13	38	26	8	13	8	5		3	Sept. 30
13	221	146	59	14	2													July 7
14	165	81	82	2														June 28
15	53	39	14															June 22
16	387	88	189	67	8	23	12											July 21
17	389	96	243	48	2													July 7
18	192	65	96	31														July 2
19	174	32	59	83														June 29
20	94	37	57															June 24
21	394	53	219	117	5													July 5
22	130	62	48	15	5													Do.
23	240	83	114	39	4													July 6
24	114	77	37															June 20
25	9	9																June 19
26	389	148	153	72	16													July 10
27	267	76	176	15														June 28
28	654	114	184	139	33	16	89	34	27	11	7							Aug. 18
29	472	44	190	58	41	22	54	25	25	13								Aug. 14
30	309	36	190	65	4	1	12	0	1									Aug. 1
31	196	47	114	35														July 3
32	42	4	32	6														June 29
33	76	0	47	29														July 2
34	121	71	50															June 23
35	98	13	74	11														June 28
36	464	67	95	116	15	19	63	62	27									Aug. 7
37	373	138	187	26	18	4												July 14
38	433	102	209	59	13	16	33	1										July 26
39	391	109	221	54	6	0	0	0	1									July 6
40	657	70	178	41	25	39	38	17	45	42	41	46	41	24	9	1		Sept. 19
41	119	40	59	15	1	3	1											July 21
Total	12,336	2,964	4,914	1,831	361	373	560	387	277	209	199	90	107	44	15	2	3	

Table XII gives a summary of these data, with some additional details from Tables VII and IX. It also compares 13 normal females from each isolation.

TABLE XII.—*A summary of the emergence data from Tables VII, VIII, IX, X, and XI.*

No.	Year.	Number of females.	Number of larvæ emerged.	Average number per female.	Emergence started.	Maximum daily emergence.	Emergence, 50 per cent.	Emergence, 75 per cent.	Emergence, 100 per cent.
.....	1912[1]	Total 26	4,258	163.7	June 16	June 18	June 25	July 1	July 15
		Normal 13	2,753	211.8	...do....	...do....	...do....	...do....	Do.
.....	1913	Total 41	12,336	297.95	June 13	...do....	June 23	June 29	Sept. 30
		Normal 13	5,211	400.8	...do....	...do....	June 24	July 10	Do.

[1] All females on twigs were dissected July 15. The isolated females in 1912 had all stopped producing young by July 15.

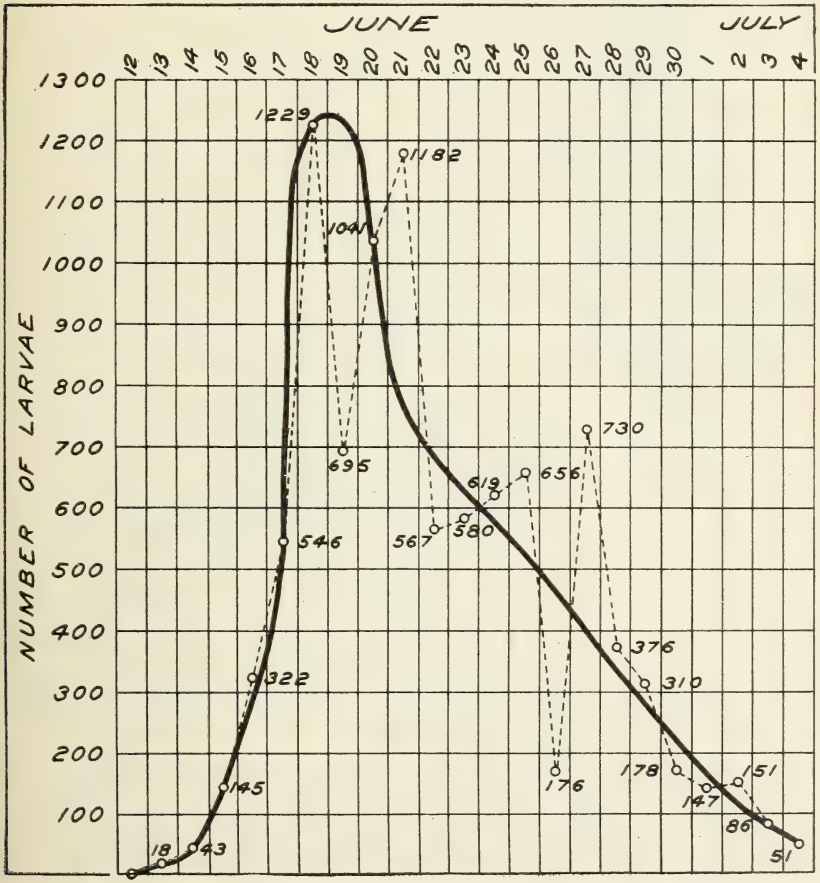


FIG. 3.—Emergence curve for the terrapin scale; first 22 days of emergence, June 13 to July 4, inclusive, Mont Alto, Pa., 1913. (Original.)

The 1912 emergence was shortened by the drying of the twigs to which the females were attached. This was due to the method of isolation. This difficulty was overcome in the 1913 record.

The larvæ of *Hyperaspis binotata* Say were more destructive in 1913 than in 1912, but on the whole both records are very true to the conditions prevailing in the orchard during the respective seasons.

For convenience in comparison and also to show the effect of weather conditions upon this emergence, two graphs, figures 3 and 4,

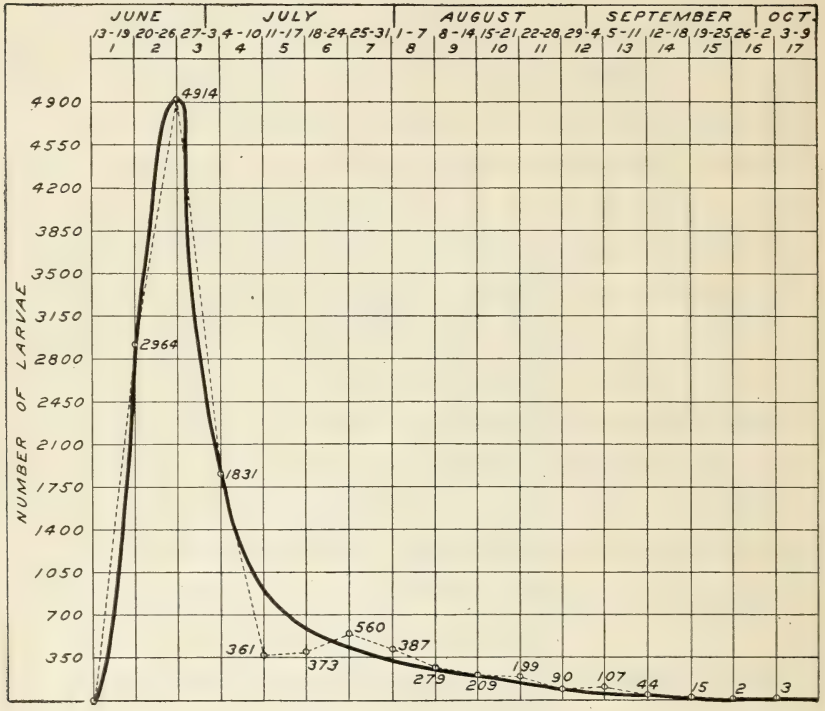


FIG. 4.—Curve of the leafward migration of the terrapin scale for the total emergence period of 1913. (Original.)

are appended. Figure 3 has a solid line added. This represents the weather correction for the curve. In figure 4, where the curve is determined from weekly observations, very little irregularity, due to the daily weather conditions, appears.

The emergence period of 1913 was moderately favorable. The temperature was high and the storms were of short duration. On June 19, 22, and 26 rain checked the emergence, but the larvæ merely remained in the brood chambers over night and emerged on the following day.

The graph of total emergence by weeks during 1913 (fig. 4) shows a very uniform curve. From the graph it appears that the major portion of the young emerged during the first three weeks of the period.

LEAFWARD MIGRATION.

The migration to the leaves begins immediately after emergence. The larvæ start emerging usually about 10 a. m., or even earlier if the temperature is high, and by 3 p. m. the daily migration has nearly ceased. At Mont Alto, Pa., during the noon hours of June 15 to 20, the branches of infested trees were swarming with countless numbers of migrating larvæ. During the leafward migration the larvæ are strongly phototropic and negatively geotropic. The time required for an individual to make this migration and to take its position upon the leaf is remarkably short.

Two hours is about the average time from emergence to the completion of the migration. Many reach the leaves and attach in less than an hour, but others, especially those that have ascended dead branches, may continue to move about for several days if a suitable leaf is not found sooner.

It is very unusual for the larvæ to relocate when they have once taken position upon a leaf, though they do this when the leaf loses its vigor. The larvæ, except in rare and unusual cases, attach to the underside of the leaves, mostly alongside and parallel to the midrib, or the larger veins. (Fig. 5.)

FIG. 5.—Peach leaf with attached larvæ of the terrapin scale. (Original.)

Larvæ usually attach to the first available leaves. The basal leaves upon an infested branch are always more heavily infested than those farther up. A sticky secretion upon the very young leaves repels the young larvæ and prevents them from attaching. The wooly coat of the fruit protects it from larvæ. Larvæ frequently crowd upon the fruit, but in their struggles to free themselves from the fuzz they invariably fall to the ground.

The rate of migration varies with the temperature and the surface upon which the larvæ are placed. Table XIII gives the rate per hour, time, temperature, and the distance traveled by five migrating larvæ of the first instar upon smoked wrapping paper. The average temperature in this experiment was very favorable, being 87° F. The rate per hour was very low, owing to the annoyance caused

the larvæ by the fine soot deposit upon the smoked paper. The distance traveled varied from 97.7 cm. to 175.8 cm. Figure 6 shows a tracing made by four of the above-mentioned larvæ.

TABLE XIII.—*Record of travel of five first-instar terrapin-scale larvæ on smoked paper, Oct. 9, 1912, Mont Alto, Pa.*

No.	Start.	End.	Time.		Distance.	Rate per hour.	Average temperature.
			Hrs.	*Min.*	*Cm.*	*Cm.*	° *F.*
1	9.26 a. m.	2 p. m.	4	34	113.7	26.54	87
2	9.26 a. m.	3.15 p. m.	5	49	175.8	26.596	86
3	11.20 a. m.	2 p. m.	2	40	97.7	36.64	89
4	10.08 a. m.	2 p. m.	3	52	99.6	25.76	87
5	9.26 a. m.	2.50 p. m.	5	24	161.7	29.94	86.7
Average						29.095	87

The larvæ are so small that they leave no trace when moving over the finest soot deposit. The deposit, moreover, retards them. In moving they are constantly exploring the surface with their antennæ, and these soon become coated with soot particles. When this happens the insect halts until the antennæ are cleaned. (For comparison with the rate of progress upon smooth, unsmoked paper, see Table XIV.)

A single larva that emerged at 12.10 p. m traveled, when placed upon plain wrapping paper, 826 cm. during the 3 hours and 20 minutes in which it was under observation. This larva traveled constantly after the first interval, and its speed was about eight times that of larvæ on sooted paper. Figure 7 shows a tracing made of this larva.

TABLE XIV.—*Record of the travel of a newly emerged larva of the terrapin scale on plain wrapping paper, July 10, 1912, Mont Alto, Pa.*

Time of observation.	Temperature.	Total distance.	Interval distance.	Rate per hour.	Average temperature.
	° *F.*	*Cm.*	*Cm.*	*Cm.*	° *F.*
12.10 p. m.	86				
12.25 p. m.	86	35.3	35.3	141.2	86
1 p. m.	86	184.4	149.1	255.6	86
1.15 p. m.	86	239.3	44.9	179.6	86
1.30 p. m.	86	298.3	59	236	86
2.10 p. m.	87.5	473.4	175.1	262.65	86.75
2.30 p. m.	87.5	557.2	83.8	251.4	87.75
3.30 p. m.	88	826	188	282	88
Average				231.356	86.9

In 1912 three experiments were performed to determine the longevity of the leafward migrants when they were unable to reach the leaves. The data from these experiments are recorded in Table XV, and summarized in Tables XVI and XVII. They show that

the migrating larvæ can live from 2 to 3 days. More than 78 per cent of the larvæ died upon the second day, and the mortality of the remainder was about equally divided between the first and third day. It was apparent that the third day was of very little value to the larvæ as they were in a state of collapse.

TABLE XV.—*Longevity of larvæ of the terrapin scale at the leafward migration.*

Experiment No.	Number of larvæ used.	Time of start.	Time of finish.	Surface.	Time of observation.	Number of larvæ dead.
I	3	July 2, 9 a. m.	July 4, 1 p. m.	Dead peach twig	July 2, 9 a. m.	0
					July 3, 9 a. m.	0
					July 4, 9 a. m.	2
					July 4, 1 p. m.	3
II	125	July 7, 12 noon.	July 10, 3.30 p. m.	Exterior surface of test tube over water.	July 7, 12 noon	0
					July 8, 8 a. m.	10
					July 9, 7.30 a. m.	108
					July 9, 12 noon	110
					July 10, 8 a. m.	122
					July 10, 3.30 p. m.	125
III	13	July 4, 8.30 a. m.	July 6, 8.30 a. m.	Inner surface of test tube over water.	July 4, 8.30 a. m.	0
					July 4, 3 p. m.	0
					July 5, 8.30 a. m.	5
					July 5, 4 p. m.	7
					July 5, 9 p. m.	7
					July 6, 8.30 a. m.	13

TABLE XVI.—*Daily mortality of larvæ of the terrapin scale from data in Table XV.*

Day of death.	Experiment I.	Experiment II.	Experiment III.	Dead, by days.	Per cent dead, by days.
First	0	10	5	15	10.63
Second	2	100	8	110	78.01
Third	1	15	0	16	11.34
Total	3	125	13	141	99.98

The summary in Table XVII shows that the average longevity for the three experiments was 2 days 9⅓ hours and the maximum longevity 3 days.

TABLE XVII.—*Maximum longevity of migrating larvæ of the terrapin scale from experiments given in Table XV.*

Experiment.	Number of specimens.	Longest life.
I	3	2 days 4 hours.
II	125	3 days.
III	13	2 days.
Average		2 days 9⅓ hours.

THE LEAFWARD MIGRATION AS A FACTOR IN THE SPREAD OF THE TERRAPIN SCALE.

The leafward migration is a strong element in the spread of the scale over the branches of infested trees, but it is not directly effective in spreading it from tree to tree unless the trees are in actual contact.

Indirectly it is one of the strongest factors in the spread of the scale. The young larvæ are not readily displaced by wind, but they sometimes drop purposely from dead twigs, especially when they have reached the tips without finding foliage. Such larvæ may fall upon foliage lower down or drift in air currents to foliage on adjacent trees. Most of them, however, perish on the ground. During windy days particles of bark and loosened leaves are carried by the wind. That wind is a prominent factor in the local spread is indicated by the fact that infestations travel through orchards in the direction of the prevailing wind. Thunderstorms sometimes come so suddenly that the young migrants are washed from the twigs before they have reached the leaves. This seldom happens, because the young do not ordinarily emerge when the humidity is high. The migrants, when displaced by rain, will float for some distance, especially if accompanied by particles of bark or other débris.

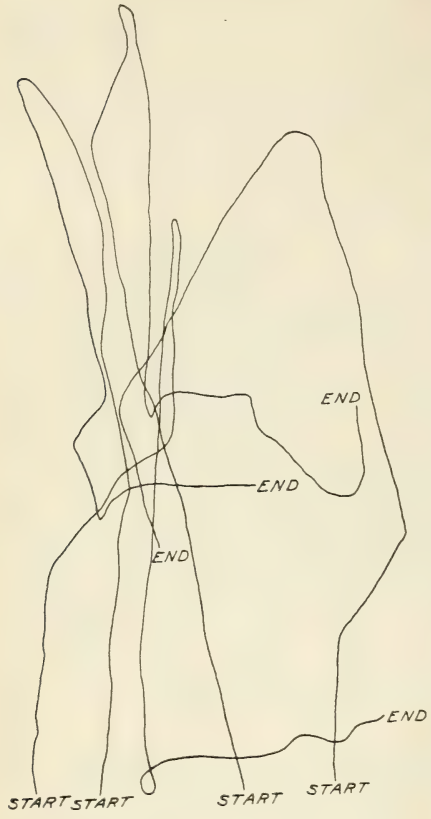


FIG. 6.—Tracing of four young terrapin scales during the leafward migration. Reduced 8 times. Temperature, 87° F. Average rate per hour, 29.095 cm. (Original.)

The spread, except as indicated, requires the aid of some transporting agent. The migrating larvæ cling readily to hairs, to feathers, and to other small objects. While the author has never taken insects with the larvæ attached, he has placed specimens of Brochymena upon branches covered with migrating young, with the result that the larvæ were soon clinging to their legs. Feathers touched lightly to the same branches were clasped by the moving young. A pair of cloth gloves placed for 10 minutes upon a branch had 20 larvæ upon them when removed. This last observation indi-

cates that orchard workers during the migrating period might unwittingly aid in the dispersal of this pest.

It is possible for larvæ of the first instar which have attached themselves to leaves to be transferred to other trees, as the following experiment shows. Thirty larvæ that had loosened themselves from a wilting leaf were placed on the foliage of another tree July 22 at 2 p. m. The first of these was found attached July 23 at 8 a. m., and all of them were attached by July 24 at 8 a. m.

Dispersal may occur at this period in at least four ways:

(1) By dropping of larvæ from dead branches, fruit, etc.

(2) By wind transportation.

(3) Through transportation by storm water.

(4) By animate agents (insects, birds, orchard workers, etc.).

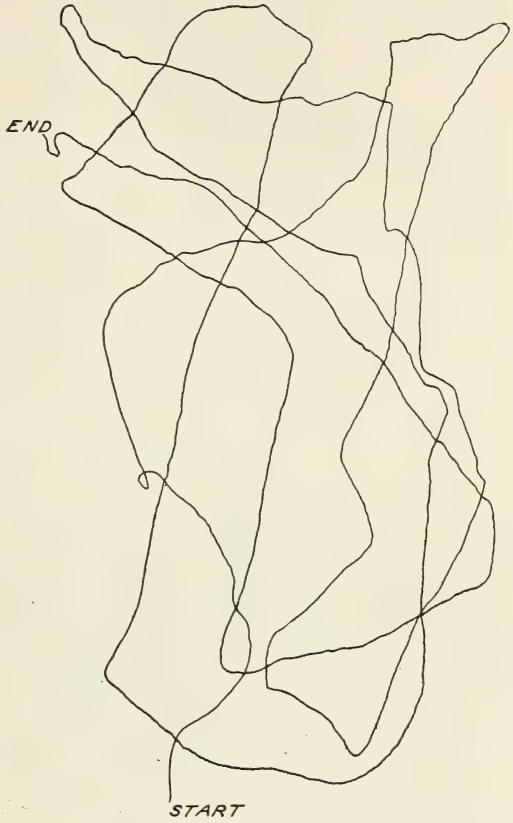


FIG. 7.—Tracings of a young terrapin scale for the first 3 hours and 20 minutes of the leafward migration. Reduced 8 times. Temperature, 86.90° F. (Original.)

MORTALITY DURING MIGRATION.

Practically all of the emerged young make a successful migration. The only exceptions are in cases where the larvæ stray upon dead branches or the fruit and are unable to return and in the case of those destroyed by the occasional attacks of predatory enemies. The mortality at this time is indicated by the small number of larvæ that fail to attach themselves to the leaves. Of the 12,336 larvæ that migrated in 1913 from the isolated scales, all but 15 successfully attached to the underside of leaves. The mortality upon the average orchard tree is slightly higher than is shown in the case of these isolated larvæ.

Size of the Larvæ at Time of Migration.

The size of the larvæ varies. Strong females produce larger young than weak ones. The larvæ are largest at the beginning of reproduction. They gradually become smaller as the season advances. Measurements made in June, 1913, of 10 larvæ give the following results: Length, maximum 0.475 mm., minimum 0.41 mm., average 44 mm.; width, maximum 0.26 mm., minimum 0.20 mm., average 0.23 mm.

Description of the Migrating Larvæ.

The distinguishing characteristics of the leaf migrant are: Average length, 0.43 mm.; average width, 0.23 mm.; color, pale translucent yellow, with reddish brown eye-spots; body very flat and oblong; antennæ with six joints; feeding tube internal and folded midway upon itself. (Pl. I, fig. 2, p. 8.) The anal plates have each a single major apical seta 0.2 mm. in length. The plates have their distal ends just reaching to the tips of the body lobes. These plates are held in a relaxed position, that is, with their adjacent edges forming an acute angle. The terminal anal plates, together with the folded feeding tube, are reliable characters for identifying the leafward migrant.

LEAF-ATTACHED LARVÆ, FIRST INSTAR.

The larvæ emerge, make their migration, and attach to the leaves during the second day after birth, but take no food until after attaching to the leaf. Death by starvation and exhaustion results during the third day after emerging provided an attachment is not made. It is doubtful whether the larvæ can live in the brood chamber more than 4 or 5 days, and at any rate they would be too weak after the fourth day to make an effectual effort to reach the leaves. In 1912 there were several periods in which it was cool and wet for four successive days. After these periods many dead larvæ were found in the brood chambers, some chambers becoming so clogged as to prevent the further escape of young.

The larva, after attaching to the underside of the leaf, retains in the main its earlier characteristics. The proboscis is thrust into the leaf tissues. The anal plates, which during the migration were carried with their adjacent edges diverging, are now held in close contact when in repose. The body lobes, which at attachment were even with the tips of the anal plates, grow steadily backward and inward until they meet behind the anal plates. By this growth the anal plates with their long setæ are made to recede from the posterior edge to a position upon the dorsal surface, as shown in Plate I, figure 3, *a*, *b*, p. 8. A thin, brittle covering of wax appears on the dorsal surface of the larvæ during the latter part of the first instar. All leaf-attached

larvæ that have their anal plates adorned with major apical setæ are in the first instar.

The growth is constant. Both length and width increase in the same ratio. In the first instar the larvæ increase their length and width about two and one-half times, but they do not noticeably increase their height. Tables XVIII and XIX show the measurements for a total of 201 larvæ at various ages during the first instar. The data in Table XVIII are from larvæ that emerged late in the season of 1912. They encountered more than the usual amount of unfavorable weather. The data in Table XIX are from larvæ that emerged in July, 1913, and that had favorable conditions. This table also shows the percentages in the first and second instars at various ages. It required about 25 days for larvæ emerging on August 9, 1912, to reach their full development (0.9 to 1 mm. long) and to molt for the first time, while those emerging July 1, 1913, reached this stage on the sixteenth and seventeenth days.

TABLE XVIII.—*Measurements of 91 first-instar larvæ during the unfavorable season of 1912, Mont Alto, Pa.*

No.	Age.	Number of specimens.	Average length.	Average width.	Emerged—
	Days.		*Mm.*	*Mm.*	
1	0.25	6	0.44	0.23	Aug. 9
2	5	5	.5325	.2044	Do.
3	6	3	.555	.287	Do.
4	7	2	.6046	.276	Do.
5	9	14	.6307	.279	Do.
6	12	6	.8467	.425	Do.
7	15	24	.8968	.439	Do.
8	21	12	.931	.50	Do.
9	22	7	.9348	.499	Do.
10	25	12	.999	.522	Do.
Total		91			

TABLE XIX.—*Measurements of 110 first-instar larvæ during the favorable season of 1913, and the percentages of larvæ on the trees in the first and second instars.*

No.	Age.	Number of specimens.	Average length.	Average width.	Emerged—	Per cent of larvæ in first instar.	Per cent of larvæ in second instar.
	Days.		*Mm.*	*Mm.*			
1	3	22	0.5176	0.2659	July 17	100	
2	5	21	.555	.2873	...do	100	
3	8	15	.7275	.39	July 1	100	
4	15	19	.94725	.5235	...do	100	
5	17	8	.9625	.521875	...do	80	20
6	18	10	.9975	.525	...do	48	52
7	19	5	.97	.52	...do	20	80
8	20	3	.9375	.525	June 26	10.9	89.1
9	21	3	.9916	.5416	July 1	7	93
10	22	3	.925	.525	June 24	10.7	89.3
11	23	1	.975	.55	June 26	3.2	96.8
12	24				July 1		100
Total		110					

The second column in each table gives the age in days. This is calculated from the time the larvæ left the brood chamber. The sixth column gives the date upon which the specimens emerged. There are added to Table XIX two columns of data to show the percentages of larvæ in the first instar and second instar at different ages. An examination of these columns will show that 50 per cent of the larvæ had passed from the first to the second instar upon the

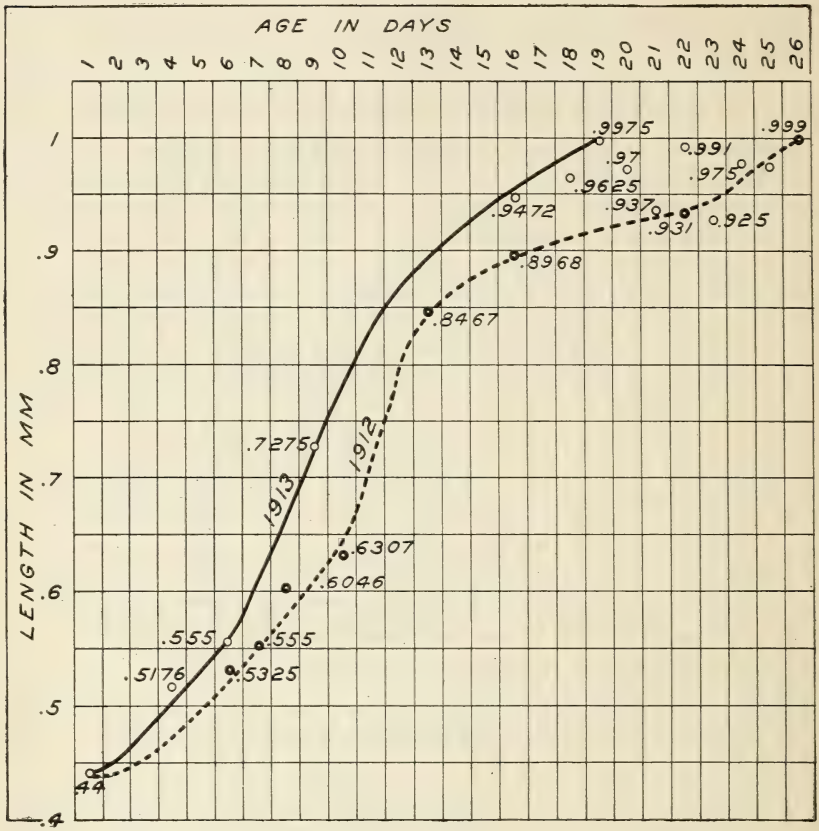


FIG. 8.—Growth curves for the first instar of the terrapin scale. (Original.)

eighteenth day, and that all had left the first instar by the twenty-fourth day. Eighteen days is the normal time spent in the first instar by larvæ during favorable seasons. Figure 8 shows the deflection of the growth curve for larvæ in the first instar which resulted from the late emergence during the unfavorable season of 1912, as compared with the curve for the favorable season of 1913. These curves are derived from the data in Tables XVIII and XIX. The curves are similar, but the broken curve shows clearly the effect of unfavorable weather in 1912 at both the beginning and the end of the instar.

Length of the First Instar.

The earliest molts were upon the sixteenth day and were observed during the very favorable weather of June and July, 1913. Eighteen days is the average length of the first instar at Mont Alto during favorable years, as shown in Table XVIII, columns 7 and 8. This time may be nearly doubled by unfavorable weather. Honeydew is excreted during this instar, but in very small quantities, and is of no economic importance.

Dispersal of First-Instar Larvæ by Leaves.

It is probable that this species is dispersed to some extent by the transportation of larvæ upon wind-borne leaves during storms. An experiment performed July 22, 1913, showed that first-instar larvæ can loosen from slowly drying leaves and that they can move about and reattach to living foliage, so that if infested leaves should lodge in adjacent trees the latter would undoubtedly become infested.

Sexual Dimorphism in the First Instar.

There are no noticeable indications of sex during this instar, except in the anal ring. It is possible in some cases to distinguish the females from the males after the fifteenth day by their increased width. At this time the length of the females is usually less than twice their width, while the length of the males is usually greater than twice their width.

Nearly all specimens are distorted by crowding, or by contact with the veins of the host (fig. 5), so that this variation in the ratio of length to width can not be depended upon for distinguishing the sexes. By dissection, however, they can be distinguished. The anal ring of the male consists of only six setæ, while the anal ring of the female consists of eight.

The First Molt.

There is no change of position at the first molt. The skin splits along the back and is worked downward and backward underneath the body. The last portion to loosen is that about the anal plates. The major apical setæ disappear at this molt; hence the absence of these is positive evidence that the first molt has passed.

The larvæ stop growing one day before molting and become more opaque. The time required to make this molt is from 5 to 30 minutes, depending upon the weather conditions and the vigor of the larvæ. The molt is usually made in the early morning.

Observations made upon 5,000 larvæ approximately one-half of which emerged from June 24 to August 9, 1912, and the others from June 24 to July 1, 1913, show that this molt may take place as early as the sixteenth day and as late as the twenty-sixth day. The aver-

age age for this molt in 1912 was 20 days, but this period is longer than in favorable years. During the favorable season of 1913 a few specimens from the rearing of July 1 made this molt on the sixteenth day, but the largest daily molts were from the eighteenth to the twenty-second day, with the maximum molt upon the eighteenth day. It is, however, very frequently delayed. Table XX gives details of the first molt as shown by three rearings in 1913 and by data obtained in orchards in 1912. It will be noticed that in all cases molting started either upon the sixteenth or seventeenth day and that it terminated in all cases by the twenty-sixth day. The 1913 rearings all had favorable weather and would undoubtedly all have given their maximum daily molts upon the eighteenth day had it not been for a local storm on that date which retarded the natural emergence for the rearings of June 24 and June 26.

TABLE XX.—*Details of the first molt of the terrapin scale from 3 rearings in 1913 and from orchard data of 1912.*

Date larvæ emerged.	Age at starting of first molt.	Per cent molted at various days specified.							Age at maximum daily molt.
		17th.	18th.	19th.	20th.	21st.	22d.	26th.	
	Days.								*Days.*
July 1, 1913	16	20	52	80	.....	.....	100	.....	18
June 24, 1913	16	2	.....	.....	.....	40	85	100	22
June 26, 1913	16	5	20	60	90	91	100	.....	19
Orchard larvæ 1912	17	.....	(1)	.....	.....	.....	.....	.....	20

1 Blanks represent days upon which no data were taken. It was impossible to determine, under orchard conditions, the percentage of the total infestation that molted at definite ages.

LEAF-ATTACHED LARVÆ, SECOND INSTAR.

The second instar lasts in favorable weather for 18 days and usually extends from the eighteenth to the thirty-sixth day. In the orchards about Mont Alto specimens can be taken in this instar at almost any time after the middle of July. The instar is at its maximum from July 20 to August 5. This stage of development is characterized by sexual differentiation, which begins very early in the instar. The female larvæ continue to widen and tend to become circular in outline, while the males lengthen and tend to become oval.

The male secretes during this instar the characteristic puparium. This is a waxy scale which forms over the dorsal surface. It is roof-like and is held in place by elastic strands which extend from points upon its edges to the surface of the leaf. (Pl. II, *a*, *e*, p. 52.) It can be recognized as early as the seventh day, but it does not reach its full development until the next to the last day of the instar, at which time growth ceases and the larva shrinks, preparatory to making the second molt.

DEVELOPMENT OF THE FEMALE.

Female Larva, Second Instar.

During the second instar the females increase in length from an average of 1 mm. to an average of 1.6 mm., and in width from an average of 0.525 mm. to 1 mm., but there is very little increase in height.

Table XXI shows the average measurements of 268 females taken at frequent intervals during this instar. These females emerged from June 20 to 26, 1913; that is, during the height of the emergence period.

Table XXI.—*Measurements of 268 female terrapin-scale larvæ of specified ages during the second instar, Mont Alto, Pa., 1913.*

No.	Emerged.	No. of specimens.	Average age at time of entering the second instar.	Age when measured.	Days in second instar.	Average length.	Average width.
	1913.		*Days.*	*Days.*		*Mm.*	*Mm.*
1	June 26	20	19	20	1	1.054	0.558
2	...do....	39	19	21	2	1.076	.590
3	June 24	17	21	22	1	1.063	.55
4	June 26	30	19	23	4	1.114	.638
5	...do....	21	19	24	5	1.257	.676
6	June 24	19	22	26	4	1.431	.775
7	...do....	16	22	27	5	1.380	.776
8	...do....	7	22	30	8	1.471	.892
9	June 21	17	22	30	8	1.395	.713
10	June 20	21	22	31	9	1.504	.835
11	June 26	16	19	32	13	1.506	.937
12	June 24	20	22	33	11	1.587	.978
13	...do....	11	22	34	12	1.575	1.012
14	...do....	14	22	36	14	1.483	.966
Total		268					

The rate of growth is very uniform throughout the second instar, but there is a variation in size among specimens of the same age. This is instanced in lines 8 and 9. Such variations are common and are usually the result of weather conditions or of low vitality in the host. In this instar there is very little growth in height, the average height at the end of the instar being about 0.11 mm. There is no change in color. The excretion of honeydew is moderate and is unimportant. The female has but slight ability to change position and seldom moves from one position to another upon the leaf. Larvæ from withering leaves, when placed upon fresh ones, mostly fail to make a satisfactory attachment.

In an experiment, twigs, the leaves of which were infested with second-instar larvæ, were placed in water. The larvæ soon loosened and migrated to the twigs. The advanced specimens made the second molt prematurely and migrated in the third instar; the young specimens, even those less than half the normal size, migrated also, but without molting. Some of the smaller specimens would undoubtedly have reattached to fresh leaf tissue had there been any on the twigs. The others attached in the normal manner to twigs.

Table XXII shows the time spent in the second instar by larvæ at Mont Alto. The orchard data are derived from the maximum daily emergence and the maximum daily molts. These data show for the season of 1912 a variation in the length of the instar from 16 to 36 days. Most of the specimens in the orchard, from July 20 to August 5, spent 20 days in the instar, while in the rearing of July 22 two-thirds of the larvæ completed the instar in 18 days.

TABLE XXII.—*Data showing the length of the second instar of the terrapin scale from 4 rearings of larvæ at Mont Alto, Pa.*

Year.	Brood.	Emergence.	Beginning of second instar.	End of second instar.	Length of the instar.
					Days.
1912....	Rearing A....	July 22	Twentieth day.....	First specimen, thirty-sixth day	16
				Maximum number, thirty-eighth day...	18
				Last specimen, forty-ninth day.....	29
	Rearing B....	Aug. 9	Twentieth day....	First specimen, thirty-sixth day.....	16
				Maximum number, thirty-eighth day...	18
				Last specimen, fifty-sixth day.....	36
1913....	Rearing A....	June 24	Twenty - second day.	First specimen, thirty-fifth day.....	13
				Maximum number, thirty-ninth day....	17
				Last specimen, fifty-third day.....	31
	Rearing B....	June 26	Nineteenth day...	First specimen, thirty-third day.....	14
				Maximum number, thirty-seventh day..	18
				Last specimen, thirty-ninth day.....	20

In 1913 the maximum daily orchard emergence was two days earlier than in 1912. The first instar required 18 days as against 20 days for the previous year. However, when the age at the end of the second instar is considered, it appears that in both seasons the maximum numbers completed the instar upon the fortieth day.

The larvæ used in Table XXII were placed upon 1-year-old peach trees. For the date of entering the instar is given the day upon which the maximum number entered it, and the date of leaving the instar is given for the first specimen, for the last specimen, and for the maximum daily number.

The table shows that the second instar may last from 13 to 36 days and that the maximum number of specimens remain in it from 17 to 18 days; the greatest number molting upon the eighteenth day.

SECOND MOLT OF THE FEMALE.

The second molt of the female coincides with that of the male and is little more than the casting of the skin in response to growth. There is no change in the structure of the appendages or of the mouth parts.

In 1912 the second molt for a rearing of 213 females that emerged July 22 extended over a period of 10 days. The maximum daily molt was upon the thirty-eighth day after emergence, and 50 per cent had molted by the fortieth day. A rearing of 100 females that emerged upon August 9, 1912, made its maximum molt upon the thirty-eighth day after emergence. One-half of the rearing molted upon that day.

In the orchards at Mont Alto, Pa., in 1912, the maximum molt was upon the fortieth day. In all the rearings there was a very short interval between the first molt and the maximum daily molt. This interval varied from 2 to 5 days, with 3 days as the normal time.

In 1913 observations were made upon two rearings, one of which emerged June 24. This rearing of 174 females made its maximum daily molt upon the thirty-ninth day. Reference to Table XXII will show that the first molt for this rearing was made upon the twenty-second day. It was slightly delayed by a storm, but the larvæ reached the maximum of the second molt on the thirty-ninth day; that is, 1 day ahead of the average time for the orchard larvæ.

TABLE XXIII.—*Age of the terrapin scale at the second molt as determined from the maximum daily molt.*

Year.	Material.	Number of specimens.	Age at the maximum daily molt.	Weather conditions.
			Days.	
1912....	Brood of July 22	213	38	Unfavorable.
	Brood of Aug. 9	100	38	Do.
	Brood of orchard [1]	1,765	37	Do.
	Average for the year		37.1	
1913....	Brood of June 24	174	39	Favorable.
	Brood of June 26	69	37	Do.
	Brood of orchard [1]	190	36	Do.
	Average for the year		37.3	

[1] These data refer to larvæ reared upon isolated twigs at Mont Alto, Pa., and not to the entire orchard brood.

The foregoing data show that the averages for the two years differ by only two-tenths of a day. Some of the individuals, however, departed 4 or 5 days from this average, while in 1912 some specimens made the molt as late as the forty-second day and in 1913 some made it as early as the thirty-second day.

LEAF PHASE OF THE THIRD INSTAR.

After molting to the third instar the females remain motionless on the underside of the leaf for a period of 1 day while they secrete a very thin dorsal scale which protects them during migration to the twigs.

The individuals vary in size in the same season, and there is a slight variation in the average size from year to year. The measurements from 11 specimens showed a minimum length of 1.387 mm. and a minimum width of 0.862 mm.; a maximum length of 1.65 mm. and a maximum width of 1.074 mm.; an average length of 1.545 mm. and an average width of 0.995 mm. The average length in 1912 was 1.465 mm. and the average width 0.974 mm. In 1913 the average length was 1.64 mm. and the average width 1.02 mm., showing an increase in size for the latter year of 0.175 mm. in length and 0.046 mm. in width.

Migration to the Twigs.

The twigward migration of the females starts about the 1st of August and reaches its maximum before the middle of the month, after which it continues in a small way until the leaves fall. In the vicinity of Mont Alto, Pa., from 80 to 90 per cent migrate between August 8 and August 20. (Pl. I, fig. 4.)

Table XXIV gives data from observations made upon 1,494 migrating females during 1912 at Mont Alto, Pa. The observations in Part I were made upon larvæ that settled naturally upon orchard trees. The material considered was isolated with tree tanglefoot August 1 and the females as they migrated were removed and counted at two-day intervals. The age at which these particular larvæ migrated is not definitely known, but was about 40 days. The rearing of July 22 (Part II) migrated from the thirty-ninth to the fiftieth day after emergence, and made its maximum daily migration August 30, which was the thirty-ninth day. The rearing of August 9 (Part III) migrated from the thirty-first to the fifty-seventh days and made its maximum daily migration upon September 15, which was the thirty-seventh day. It is evident from a comparison with figure 11 that the maximum in Part III was retarded. A cold wave, which started September 7, retarded the maximum daily migration, causing it to be nearly a week after the start.

Table XXIV.—*The time of the twigward migration of 1,483 female larvæ of the terrapin scale, Mont Alto, Pa., 1912.*

Part.	Material observed.	Number of larvæ.	Twigward migration.		Part.	Material observed.	Number of larvæ.	Twigward migration.	
			Date.	Number migrated.				Date.	Number migrated.
I.....	Orchard larvæ, Mont Alto, Pa.	976	Aug. 12	0	III...	Rearing of August 9.	294	Sept. 8	0
			14	283				9	2
			16	176				10	5
			18	202				11	13
			20	120				12	24
			22	65				13	23
			24	33				14	18
			26	32				15	65
			28	24				16	20
			30	13				17	18
			Sept. 1	10				18	20
			3	12				19	11
			5	6				20	24
II....	Rearing of July 22.	213	Aug. 30	61				21	5
			31	19				22	10
			Sept. 1	6				23	5
			2	50				24	8
			3	20				25	9
			4	17				26	3
			5	14				27	3
			6	10				28	1
			7	7				29	0
			8	4				30	0
			9	3				Oct. 1	1
			10	2				2	0
			11	0				3	0
			12	0				4	0
								5	6
						Total.....	.....	.....	1,483

The orchard larvæ considered in Table XXIV, Part I, had very favorable weather during their twigward migration. The relation of this migration to the prevailing temperature is shown graphically in figure 9. The migration curve shows the shortness of the interval between the start of migration and its maximum.

The migration started on August 13 and was 50 per cent complete upon August 17. Thus, one-half of the migration was made during

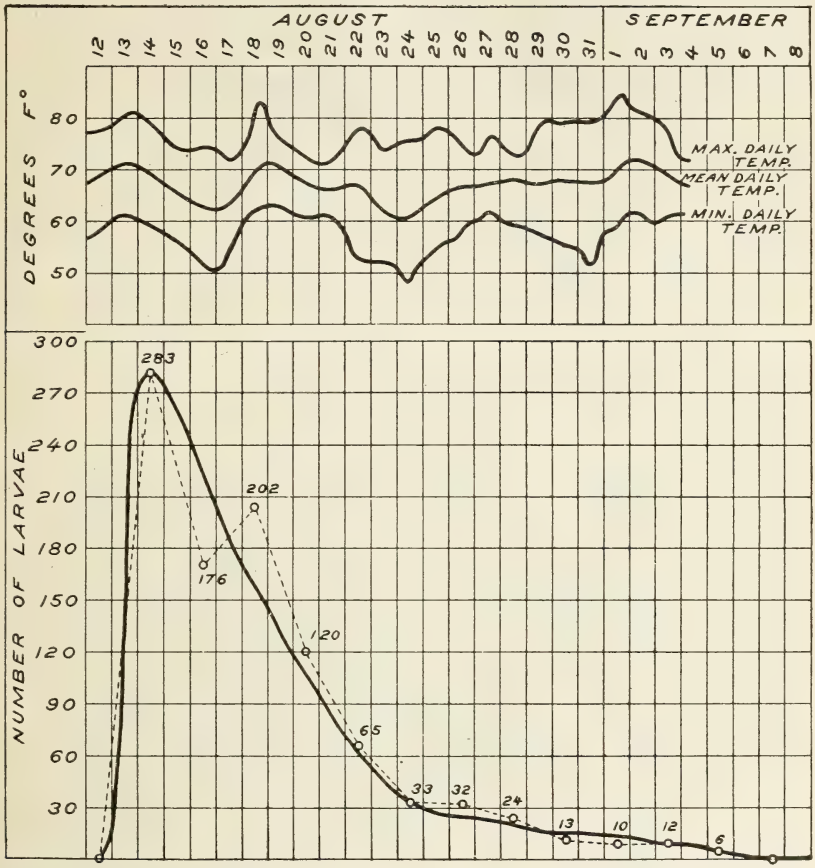


FIG. 9.—Curve of the twigward migration of the terrapin scale for the orchard larvæ of 1912. (Original.)

the first four days of the period. This curve is typical for the migration in favorable seasons.

The larvæ considered in Table XXIV, Part II, encountered very unfavorable weather during the period of migration. Cold interfered at the beginning, and rain continued throughout most of the period. The effects of these conditions are shown graphically in figure 10. The solid curve represents a normal migration, the dotted curve the migration under prevailing conditions. This graph

also includes the data for rainy and clear days. August 28 was clear and favorable and the following day was rainy. August 30 was clear, and migration started. August 31 to September 2 was

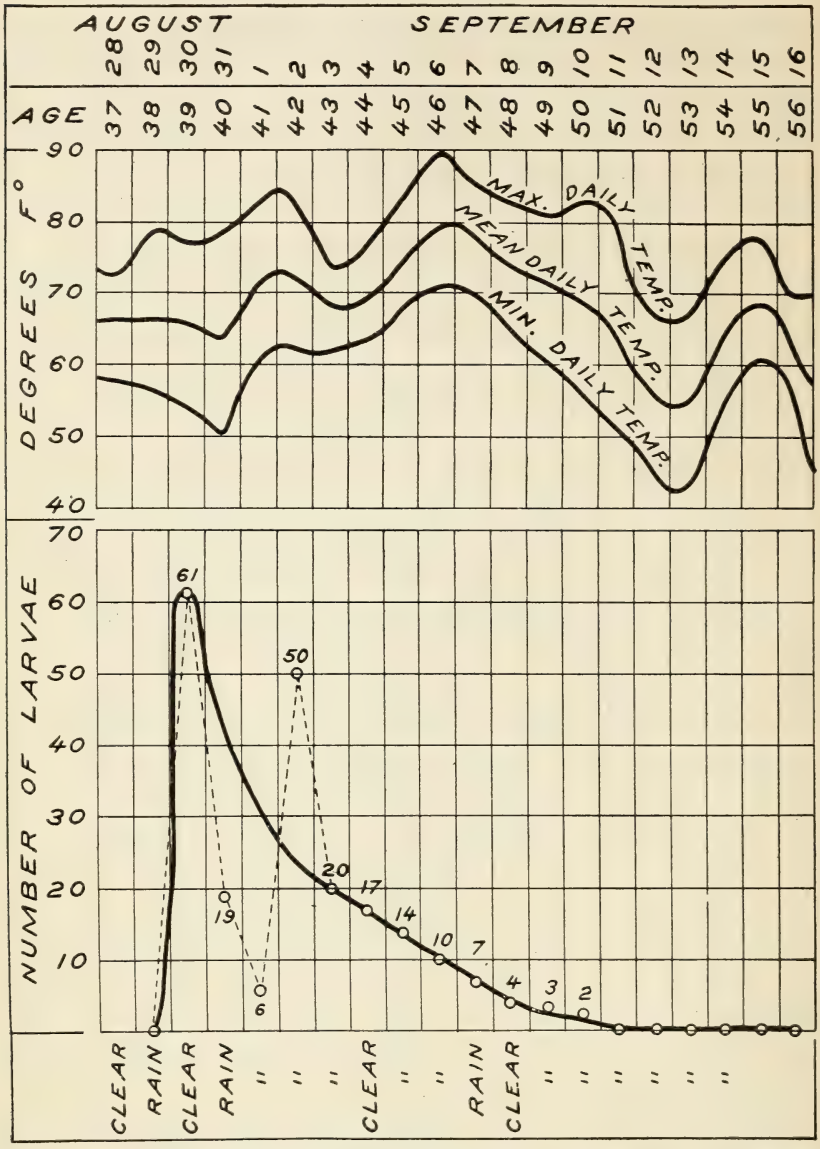


FIG. 10.—Curve of the twigward migration of the terrapin scale for a rearing that emerged July 22, 1912. (Original.)

rainy, but on the last of these days it was clear and hot in the afternoon, thus permitting a heavy migration. The remainder of the period was clear, except for slight rains upon September 3 and 7.

During the migration of the rearing of July 22 the maximum daily temperature rose gradually from 73° F. on August 28 to 85° F. upon September 1, after which it fell to 74° F. upon September 3, and then rose abruptly to 90° F. upon September 6. It then dropped to 67° F. upon September 12. The average daily temperature remained nearly constant at 66° F. from August 28 to August 31,

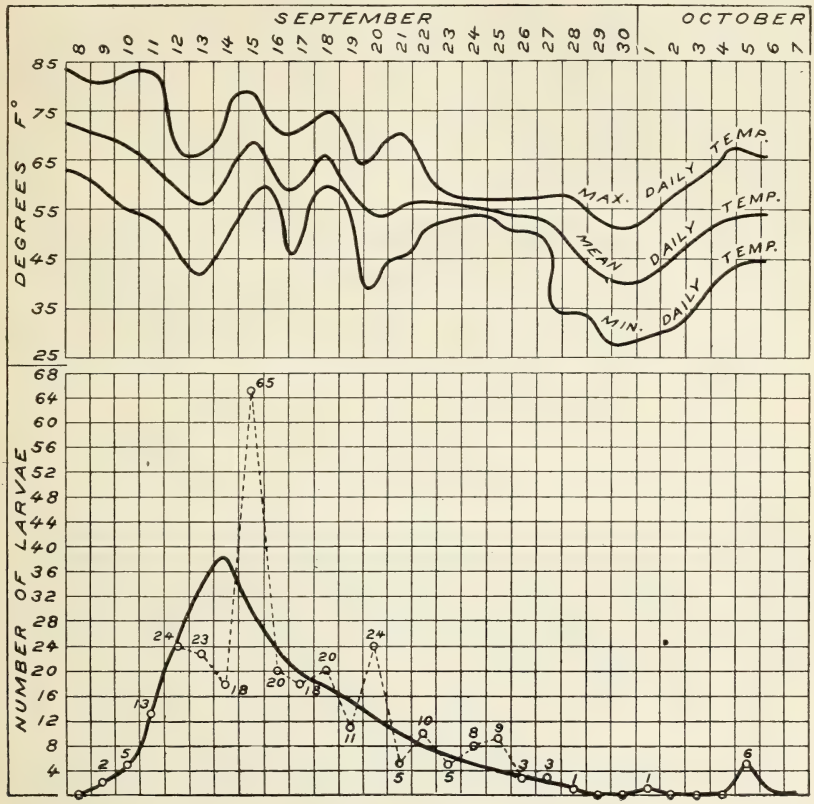


FIG. 11.—Curve of the twigward migration of the terrapin scale for a rearing that emerged August 9, 1912. (Original.)

when it rose abruptly to 73° F. upon September 1. During September 2 and 3 it made a gradual drop to 68° F., and then rose in a gradual way to 80° F. upon September 6. This was followed by a gradual drop to 54° F. upon September 12. This rearing gave its maximum daily migration when 39 days old and its 50 per cent of migration four days later.

The larvæ considered in Part III of Table XXIV were a late rearing. They had favorable weather to near the end of the second instar, but very unfavorable weather during the twigward migration. The

relation of the temperature to the migration of this rearing is shown in figure 11.

This migration extended from September 8 to October 5, 1912, under unfavorable temperature conditions. There was a drop in the average daily temperature from 71° F. on the first day of migration to 56° F. on the sixth day (September 13). This was followed by a favorable day, when the average temperature rose to 69° F., after which it dropped gradually to 40° F. at the end of September. There was a rainstorm of three days' duration, September 23, 24, and 25, but it came too late to modify the rate of migration to any extent. Under these conditions 95 per cent of the rearing had migrated by the end of the tenth day of migration, or by the fortieth day after emerging. The maximum daily migration was made by this rearing upon the seventh day after the start of migration; that is, upon the thirty-seventh day after emerging. A comparison of the curves, figures 9 to 11, shows that the curve for optimum conditions (fig. 9) tends to have a perpendicular ascending slope and a very steep receding slope, and that unfavorable conditions tend to flatten the curve and to cause serrations in the slopes.

TIME REQUIRED FOR MIGRATION.

The migration is made during the hottest part of the day. Usually very few migrating specimens can be taken until after 12.30 p. m., because of the low morning temperatures. The larvæ start upon this migration when the temperature reaches 70° F. By 1.30 p. m. larvæ are usually moving in great numbers upon the twigs. By 3 p. m. nearly all migrants have selected their locations and permanently established themselves.

LONGEVITY OF MIGRANTS.

In case the twigward migrants are prevented from attaching, they can live for 2 days, and a small percentage even for 3 days before dying.

The following experiment was made to determine the longevity of a twigward migrant when prevented from attaching. A quantity of material was kept under observation from August 30, 1913, until one of the larvæ was observed to start upon its migration. This specimen was then placed upon wrapping paper for observation. The details of these observations are shown in Table XXV.

TABLE XXV.—*Rate per hour and distance traveled by a migrating larva of the terrapin scale upon wrapping paper during the total time of the twigward migration, Mont Alto, Pa., 1912.*

LARVA NO. 1.

	Observed—	Interval.	Distance.	Rate per hour.	Temperature.
		Min.	*Cm.*	*Cm.*	° *F.*
Aug. 30	2.45 p. m.				70
	3.15 p. m.	30	30.6	61.2	84
	3.30 p. m.	15	27.8	111.2	88
	4 p. m.	30	62	124	90
	4.30 p. m.	30	61.5	123	80
	4.45 p. m.	15	16.2	64.8	78
	5 p. m.	15	15.4	61.6	77
	5.15 p. m.	15	9.1	36.4	76
	6 p. m.	45	9.3	12.4	72
	Total	3 h. 15 m.	231.9		
Aug. 31	2.30 p. m.				70
	3.15 p. m.	45	8	10.6	86
	3.30 p. m.	15	1.7	6.8	88
	4.15 p. m.	45	17.3	23.06	82
	4.30 p. m.	15	3.2	12.8	78
	6 p. m.	90	8.6	5.7	75
	6.30 p. m.	30	2.7	5.4	72
	Total	4 h.	41.5		
Sept. 1	8.45 a. m.				70
	9.20 a. m.	35	3.6	6.17	72
	9.30 a. m.	10	.4	2.4	80
	10 a. m.	30	7.9	15.8	86
	11 a. m.	60	25.1	25.1	88
	12 noon	60	12.1	12.1	84
	Total	3 h. 15 m.	49.1		

Migration, first day: Migration started at 2.45 p. m., and continued until 6 p. m., when it stopped. The larva remained motionless all night. During the time of migration, which was 3¼ hours, the larva traveled 231.9 cm. It traveled at a rate of 124 cm. per hour from 3.30 p. m. to 4 p. m., with a rate of 123 cm. per hour from 4 to 4.30 p. m. The rate then fell off rapidly after 4.30, being 36.4 cm. per hour for the interval from 5 to 5.15 p. m., and only 12. 4 cm. per hour for the interval from 5.15 p. m. to 6 p. m. The temperature during this migration rose gradually from 70° F. at 2.45 p. m. to 90° F. at 4 p. m., and then fell to 72° F. at 6 p. m. The highest rate of travel therefore coincided closely with the time of highest temperature.

Migration, second day: The larva remained motionless from 6 p. m., August 30, until 2.30 p. m., August 31, when it again started to migrate and continued until 6.30 p. m., an interval of 4 hours, during which it showed signs of exhaustion and traveled only 41.5 cm. The rate per hour gradually increased from the start until it reached a maximum of 23.06 cm. per hour for the period 3.30 p. m. to 4.15 p. m., after which it dropped to 12.8 cm. per hour during the next interval and then to 5.4 cm. per hour for the last interval. The temperature during this second day's migration was slightly lower than on the previous day. The temperature at the resumption of migration, 2.30 p. m., was 70° F., from which it rose rapidly to a maximum of 88° F. at 3.30 p. m., and then dropped gradually to 72° F. at 6.30 p. m.

Migration, third day: The third day was very warm. The larva had remained motionless from 6.30 p. m., August 31, to 8.45 a. m. of the following day, at which time it resumed migration and continued until 12 noon, when it died, after traveling for 3¼ hours, during which time it advanced 49.1 cm. The rate of travel, which was very low, reached its maximum of 25.1 cm. per hour in the interval ending at 11 a. m., after which it dropped to 12.1 cm. per hour for the interval between 11 a. m. and 12 noon. The temperature during the third day was very favorable. It reached 70° F.

at 8.45 a. m., at which time the larva resumed its migration. At 9.30 a. m. the temperature was 80° F., at 10 a. m. 86° F., and at 11 a. m. 88° F., from which hour it dropped to 84° F. at noon, when the experiment was terminated by the death of the larva.

Ordinarily larvæ start migrating when the temperature reaches 70° F., and the rate of travel increases in nearly the same ratio as the increase in temperature above 70° F. Larvæ, if unattached, become motionless when the temperature falls below 72° F. The female

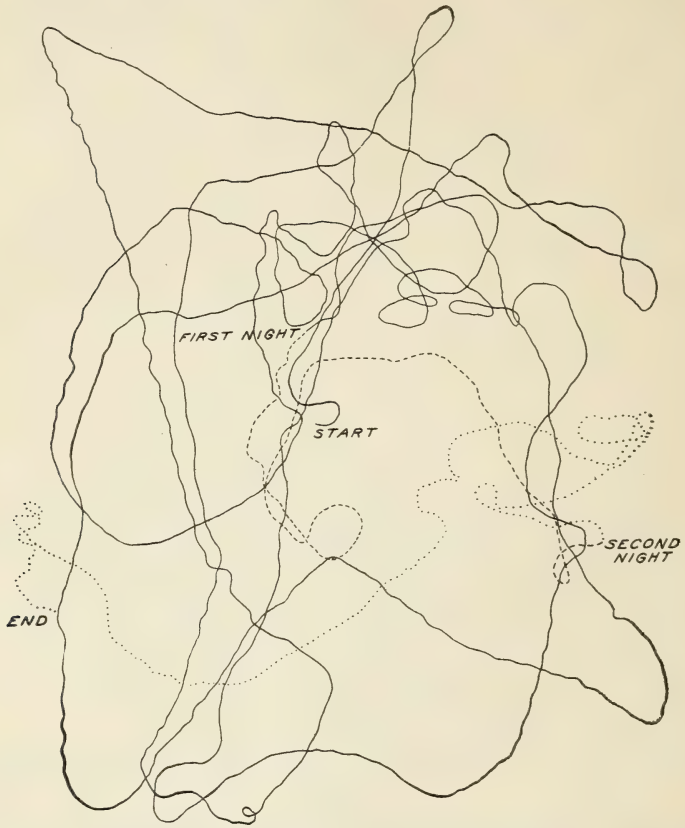


FIG. 12.—Tracing of the total twigward migration of a female larva of the terrapin scale. Reduced 8 times. Total distance traveled, 322.5 cm. (Original.)

under observation started migration August 30 at 2.40 p. m., and died September 1 at 12 noon, having lived 2 hours and 40 minutes less than 3 days, and having traveled over smooth paper a distance of 322.5 cm. (10½ feet). (Fig. 12.) This was undoubtedly farther than the average specimen is able to travel upon its host plant. *There is therefore very little chance of the larvæ crawling to adjacent trees unless the limbs are in contact.*

A second female larva (Table XXV), captured August 26, during the first day of migration, was placed upon wrapping paper at 2.25

p. m. This larva traveled 192 cm. in 2 hours and 35 minutes at an average rate per hour of 74.84 cm. (Fig. 13.)

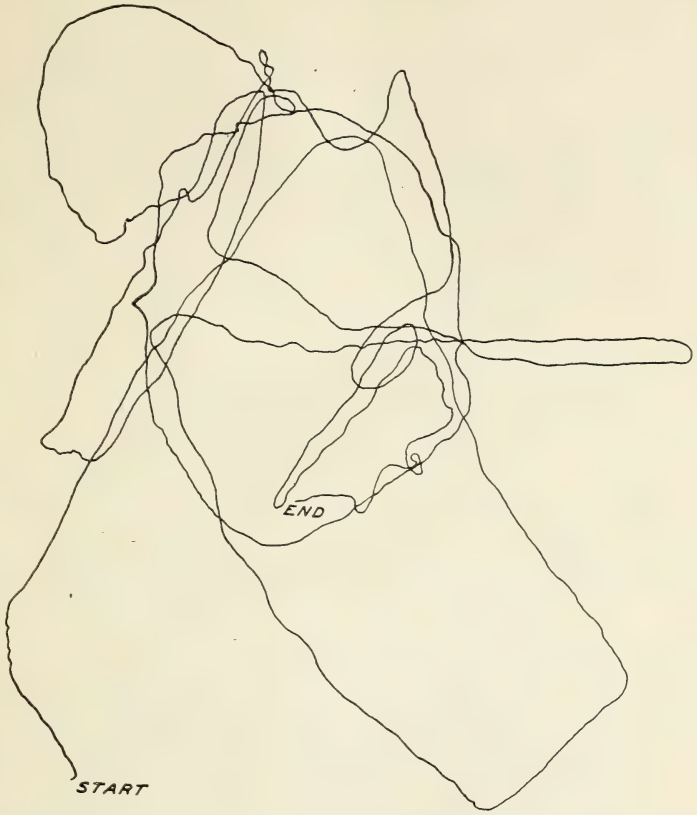


FIG. 13.—Tracing of a female larva of the terrapin scale for 2 hours and 35 minutes during the first day of the twigward migration. Distance traveled, 192 cm. (Original.)

TABLE XXVI.—*Rate per hour and distance traveled by two migrating larvæ of the terrapin scale on wrapping paper.*

Larva number.	Observed—	Interval.	Distance.	Rate per hour.
		Min.	*Cm.*	*Cm.*
2	2.25 p. m.			
	2.47 p. m.	22	58	158.88
	3.40 p. m.	53	57	64.33
	4 p. m.	20	31.6	94.8
	4.45 p. m.	25.7	25.7	34.26
	5 p. m.	15	21	84.00
Total		2 hrs. 35 m.	192	74.84
3	11 a. m.			
	11.30 a. m.	30	53.5	101.5
	12 noon	30	45	90.
	12.30 p. m.	30	48.1	96.2
	1 p. m.	30	37.5	75
Total		2 hrs.	181.1	92.05

A third larva, Table XXVI, taken September 1, 1912, at 11 a. m., while in the first day of migration, gave a maximum rate per hour of 101 cm., at 88° F., and an average rate for 2 hours of 92.05 cm. (Fig. 14.)

The rate of migration depends both upon the temperature above 70° F. and upon the length of time that has elapsed since the migration started.

It is very exceptional for specimens to require more than one day for the twigward migration. More than 90 per cent of the females

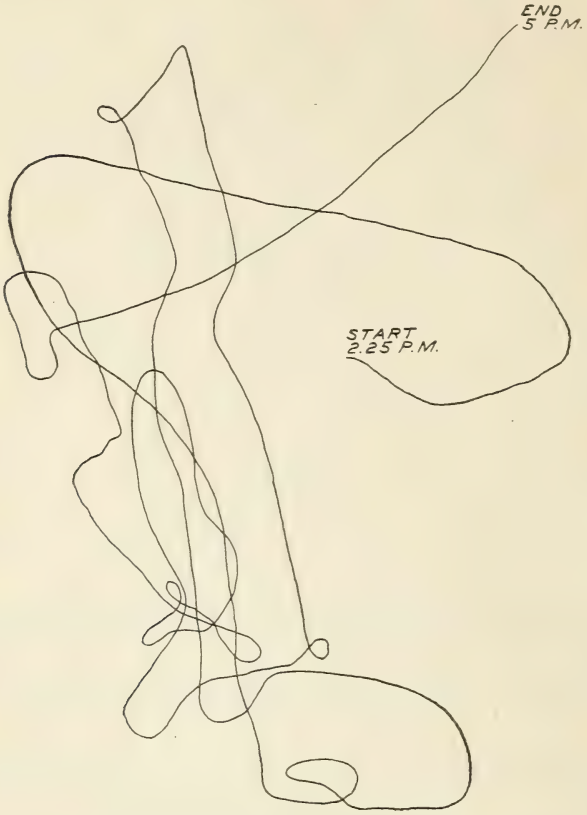


FIG. 14.—Tracing of a female larva of the terrapin scale for the first two hours of the twigward migration. Reduced 8 times. Total distance, 184.1 cm. (Original.)

complete this migration during the first 4 hours. Females may occasionally shift to a more favorable position during the second and third days' sojourn upon the twigs, but after this they remain in one place.

During the day preceding the twigward migration the female larvæ secrete a thin scale which covers the dorsal surface and gives rigidity to the flat, leaf-shaped body. The larvæ in migrating pass down the petiole and move along the twigs toward the region of greatest illu-

mination. They finally reach the tips of the twigs, where they locate by preference upon the basal part of the young growth. Many, however, locate upon 1-year-old wood, and a few upon the 2-year-old wood. Other parts of the tree are very seldom infested. The larvæ settle by preference upon the underside of horizontal limbs and upon the unshaded side of vertical branches. There is a tendency for them to group themselves in rows upon the illuminated sides of the twigs. The individual scales within these rows are not necessarily in alignment, either with their neighbors or with the axis of the twig. This linear arrangement results solely from their instinctive desire to locate in the area of greatest illumination, which, from the nature of the twigs upon which they locate, is always many times longer than wide. During migration the mortality is very low.

The females are very flat and have the pale yellow color of the preceding stages. This color appears rather lighter than in the second instar, due, no doubt, to the effect of the nearly transparent dorsal scale. The only colored portions at this time are the brown eyespots and the chitinized anal plates.

Specimens measured in 1912 and in 1913 were from 1.23 to 1.57 mm. in length and from 0.65 to 1.12 mm. in width, the average height being about 0.1 mm. The average size for both seasons was, length 1.47 mm., width 0.98 mm.

The Female Upon the Twig: Development During the First 20 Days.

After attaching to the twigs the young females begin a period of rapid growth. A small red blotch, which appears over the oral region either during the migration or immediately after it, begins at once to enlarge and to form itself into a narrow band of a reddish-brown color which extends backward along the middorsal line until by the sixth day it reaches the anal plates. (Fig. 15, *a*.) Meanwhile the dorsum changes from a flat to a mildly arched surface and the larva increases from about 1.54 to 1.65 mm. in length and in width from 1.03 to 1.29 mm. When the dorsal band reaches the anal plates it forks. Each fork when developed equals the original band in width and is slightly longer than wide. These forks start about the sixth day and are about one-half completed by the eighth day. From the sixth to the tenth day there is a very decided arching of the dorsum. Growth is greatest just in front of the anal plates, and the elongation of the dorsum at this place first constricts and then breaks the dorsal band, leaving a short piece of it attached to the forked portion that is forming about the anal plates. (Fig. 15, *b*.) Later the anterior piece is displaced forward and shrinks until it becomes inconspicuous just above the oral region. About the eleventh day after migrating, the forks of the dorsal band are completed. This band is a secondary sexual character, which, after copulation, fades and blends with the

reddish-brown ground color. The rent between the two parts remains unpigmented and shows in mature specimens as the characteristic dorsal stripe. (Pl. I, fig. 5, *b*, p. 8, and text fig. 15, *d*.)

Up to and including the eighth day the general aspect is strictly larval, except for the slight arching of the dorsum and for the dorsal

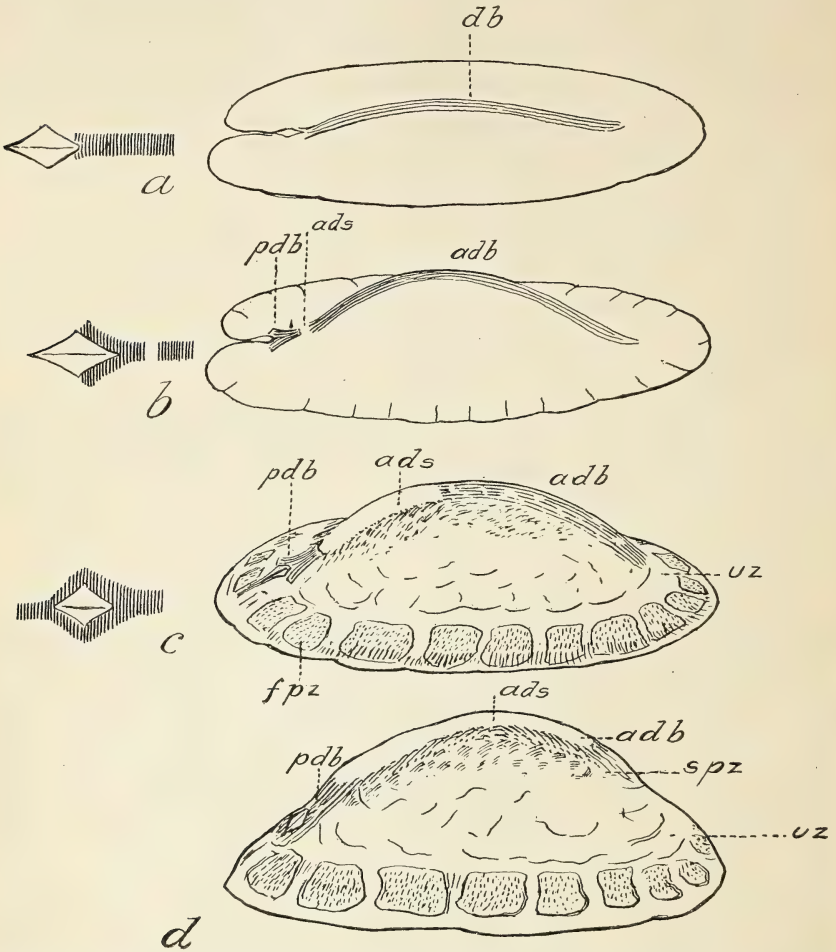


FIG. 15.—Diagrammatic representation of the color and markings of the female terrapin scale: *a*, Larva, seventh day upon the twig; *b*, larva, eleventh day upon the twig; *c*, larva, fifteenth day upon the twig; *d*, larva, twentieth day upon the twig and after; *db*, dorsal band; *adb*, anterior segment of dorsal band; *pdb*, posterior segment of dorsal band; *fpz*, first pigment zone; *spz*, second pigment zone; *ads*, adult dorsal stripe; *uz*, unpigmented zone. (Original.)

band. At the ninth day the female is about equally adult and larval in appearance. At this time the pale yellow body color of the larva begins to turn to a reddish amber and the characteristic crimps at the margin of the derm (fig. 15, *b*) begin to appear. In the depressions formed by the crimping, a brownish pigment develops and marks

them in sharp contrast with the narrow ridges of the crimps. These pigmented depressions blending form the first pigment zone or marginal pigmentation. (Fig. 15, *fpz.*) By the fourteenth day the female has become decidedly adult, both in shape and color. The first pigment zone now reaches completely around the dorsum and extends upward as far as the anal plates; the dorsal band has blended with the reddish-brown ground color, and a second zone of pigmentation has formed about the rent in the original dorsal band, thus transforming it into the permanent reddish-brown stripe which is so characteristic of the mature female. (Fig. 15, *ads.*) The second zone of pigment is composed of dark-brown granules similar to those in the marginal region. It surrounds the amber-colored gap in the original dorsal band and extends downward and outward nearly to the marginal zone, from which it is separated by an irregular unpigmented zone (fig. 15, *uz*) which lies parallel to the edge of the dorsum at about the height of the anal plates. By the twentieth day the female has assumed both the characteristic shape and color of the adult, but the general color is not so bright as in the case of older specimens. After the twentieth day there is no change in the color pattern. The pigmentation, however, deepens and the insect continues to grow, but at a decreasing rate, until it hibernates.

The data in Table XXVII show in detail the development of the female up to and including the fifteenth day after attaching to the twig. A very rapid growth is also shown during this period. The ground color changes from light yellow to reddish brown; the dorsal band develops and breaks and the adult pigmentation starts.

To obtain more extended observations upon the twig-attached females, 100 larvæ were taken August 15, 1913, while making the twigward migration, and placed upon a vigorous potted peach tree. This tree was kept under orchard conditions and such of the specimens as had accessible locations were numbered and observed from time to time through a Zeiss binocular. These observations were continued to the sixty-seventh day after migrating. Data from these specimens are given in Table XXVIII; they supplement Table XXVII.

TABLE XXVII.—*Details of the growth of the female terrapin scale during the first 15 days upon the twig, Mont Alto, Pa., 1913.*

No.	Original symbol.	Emerged.	Observed.	Age.	Period on twig.	Length.	Width.	General body color.	Dorsal band.	Anal Y.	Edge crimped.	Adult pigmentation.
				Days.	*Days.*	*Mm.*	*Mm.*					
1	A 1″	June 24	Aug. 7	44	1	1.625	1.1	Light yellow	Just starting	None	Not	None.
2	A 2″	do	do	44	1	1.65	.975	do	do	do	do	Do.
3	A 3″	do	Aug. 6	44	1	1.525	1.1	do	do	do	do	Do.
4	B 10″	do	Aug. 8	45	2	1.75	1.2	do	Half completed	do	do	Do.
5	B 11″	do	do	45	2	1.675	1.075	do	do	do	do	Do.
6	B 12″	do	do	45	2	1.525	1.15	do	do	do	do	Do.
7	B 12″	do	Aug. 11	48	2	1.35	.925	do	One-fourth	do	do	Do.
8	A 3″	do	Aug. 10	47	4	1.75	1.15	do	Nearly	do	do	Do.
9	1″	do	Aug. 13	50	4	1.475	.95	do	Complete	do	do	Do.
10	A 2″	do	Aug. 10	47	4	1.75	1.1	do	do	do	do	Do.
11	4	do	Aug. 11	48	5	1.375	1.025	do	do	do	do	Do.
12	B	do	Aug. 13	50	7	1.675	1.025	do	One-fourth	do	do	Do.
13	A 2″	do	do	50	7	1.775	1.125	do	Complete	do	do	Do.
14	4	do	do	50	7	1.375	.975	do	do	Forming	do	Do.
15	C	do	Aug. 14	51	8	1.65	1.05	do	do	do	do	Do.
16	D	do	do	51	8	1.35	1.00	do	do	do	do	Do.
17	2	do	Aug. 11	48	8	1.85	1.275	do	do	do	do	Do.
18	3	do	do	48	8	2.00	1.5	do	do	do	do	Do.
19	2	do	Aug. 13	50	10	1.85	1.3	do	do	Formed	do	Do.
20	3	do	do	50	10	1.9	1.425	Reddish yellow	do	do	Crimped	Do.
21	A	do	Aug. 14	51	11	1.875	1.475	Reddish brown	Broken	do	Slightly	First zone forming.
22	B	do	do	51	11	1.95	1.55	do	do	do	Not	None.
23	C	do	Aug. 18	55	12	1.8	1.225	do	do	do	do	Do.
24	B	do	do	55	12	1.5	1.125	do	do	do	Crimped	First zone advanced.
25	E	do	do	55	15	1.8	1.45	do	do	do	do	First zone forming.
26	B	do	do	55	15	2.00	1.55	do	do	do	do	First zone advanced.

TABLE XXVIII.—*Growth and color changes of female terrapin scales from the fourth to the sixty-seventh day after the twigward migration, Mont Alto, Pa., 1913.*

Observation No.	Number of specimens observed.	Date observed.	Period on twig.	Length.	Width.	Height.	General body color.	Degree of completion of the dorsal band.	Condition of the dorsal band.	Degree of completion of the anal band.	Condition of edge.	Amount of pigmentation as in adult.
			Days.	*Mm.*	*Mm.*	*Mm.*						
1	1	Aug. 19	4	1.525	1.125		Light yellow	Three-fourths	Unbroken.	Incomplete	Uncrimped	None.
2	2	...do	4	1.575	.925		...do	Nearly	...do	...do	...do	Do.
3	3	...do	4	1.525	1.05		...do	...do	...do	...do	...do	Do.
4	4	...do	4	1.7	1.15		Turning amber	Three-fourths	...do	...do	Slight crimp	Do.
5	7	...do	4	1.8	1.15		Light yellow	Nearly	...do	...do	Uncrimped	Do.
6	8	...do	4	1.72	1.15		...do	Incomplete	...do	...do	...do	Do.
7	9	...do	4	1.7	1.15		...do	Complete	...do	...do	...do	Do.
8	10	...do	4	1.75	1.075		...do	Incomplete	...do	...do	...do	Do.
9	11	...do	4	1.6	1.15		...do	Nearly	...do	...do	...do	Do.
10	12	...do	4	1.6	1.05		...do	...do	...do	...do	...do	Do.
11	13	Aug. 20	5	1.575	1.2		...do	Complete	...do	...do	...do	Do.
12	14	...do	5	1.6	1.1		...do	...do	...do	...do	...do	Do.
13	15	...do	5	1.625	1.075		Light amber	...do	...do	...do	Slight crimp	Do.
14	16	...do	5	1.575	1.00		Light yellow	...do	Breaking	...do	...do	Do.
15	17	...do	5	1.575	1.00		...do	...do	Unbroken	...do	Slight crimp	Do.
16	8	...do	5	1.75	.95		...do	...do	Breaking	...do	...do	Do.
17	20	...do	5	1.625	1.50		...do	...do	...do	...do	...do	Do.
18	21	...do	5	1.6	1.025		...do	Incomplete	Unbroken	...do	Uncrimped	Do.
19	22	...do	5	1.55	.925		...do	Three-fourths	...do	...do	...do	Do.
20	1	Aug. 23	8	1.6	1.1		...do	Complete	Broken	...do	...do	Do.
21	2	...do	8	1.70	1.075		Amber color	...do	...do	Complete	Slight crimp	Do.
22	3	...do	8	1.525	1.05		Light color	...do	Breaking	Partly complete	...do	Do.
23	4	...do	8	1.725	1.275		Reddish amber	...do	Broken	One-half complete	...do	Do.
24	7	...do	8	1.9	1.325		...do	...do	...do	One-fourth complete.	...do	Do.
25	8	...do	8	1.75	1.275		Light amber	...do	...do	Nearly complete	...do	Do.
26	9	...do	8	1.7	1.175		Light yellow	...do	...do	Complete	Uncrimped	Do.
27	11	...do	8	1.625	1.225		...do	...do	Breaking	Incomplete	...do	Do.
28	12	...do	8	1.65	1.15		Reddish amber	...do	Broken	Complete	Slight crimp	Trace.
29	13	...do	8	1.625	1.255		...do	...do	...do	...do	...do	Do.
30	14	...do	8	1.75	1.125		...do	...do	...do	...do	Crimped	One-half first zone.
31	15	...do	8	1.625	1.150		...do	...do	...do	...do	...do	Do.
32	16	...do	8	1.75	1.125		Light yellow	...do	...do	Partly complete	Uncrimped	None.
33	1	Aug. 26	11	1.65	1.20		Reddish amber	...do	...do	Complete	Crimped	Evident.
34	2	...do	11	1.725	1.12		...do	...do	...do	...do	...do	Do.
35	7	...do	11	1.925	1.325		...do	...do	...do	...do	Slight crimp	None.
36	8	...do	11	1.75	1.375		Light amber	...do	...do	...do	Crimped	First zone.
37	14	Aug. 29	14	2.075	1.5		...do	...do	...do	...do	...do	First and second zones.
38	15	...do	14	1.85	1.2		...do	...do	...do	...do	...do	First zone complete.
39	16	...do	14	1.875	1.5		...do	...do	...do	...do	...do	Do.

TABLE XXVIII.—*Growth and color changes of female terrapin scales from the fourth to the sixty-seventh day after the twigward migration, Mont Alto, Pa., 1913*—Continued.

Observation No.	Number of specimens observed.	Date observed.	Period on twig.	Length.	Width.	Height.	General body color.	Degree of completion of the dorsal band.	Condition of the dorsal band.	Degree of completion of the anal band.	Condition of edge.	Amount of pigmentation as in adult.
			Days.	*Mm.*	*Mm.*	*Mm.*						
40	17	Aug. 29	14	1.875	1.25		Light amber	Complete	Broken	Complete	Crimped	Slight.
41	18	...do	14	1.925	1.375		...do	...do	...do	...do	...do	First and second zones.
42	21	...do	14	1.8	1.2		...do	...do	...do	...do	...do	None.
43	22	...do	14	1.65	1.25		Reddish amber	...do	...do	...do	...do	First zone.
44	23	...do	14	2.05	1.375		...do	...do	...do	...do	...do	Do.
45	1	Sept. 3	19	2.00	1.5		...do	...do	...do	...do	...do	First and second zones.
46	2	...do	19	1.96	1.49		...do	...do	...do	...do	...do	Do.
47	3	...do	19	1.913	1.588		...do	...do	...do	...do	...do	Do.
48	4	...do	19	1.96	2.05		...do	...do	...do	...do	...do	Do.
49	7	...do	19	2.146	1.866		...do	...do	...do	...do	...do	Do.
50	9	...do	19	2.05	1.68		...do	...do	...do	...do	...do	Do.
51	11	...do	19	1.866	1.68		...do	...do	...do	...do	...do	Do.
52	12	...do	19	2.05	1.726		...do	...do	...do	...do	...do	Do.
53	14	...do	19	2.24	1.68		...do	...do	...do	...do	...do	Do.
54	15	...do	19	1.96	1.493		...do	...do	...do	...do	...do	Do.
55	16	...do	19	2.053	1.54		...do	...do	...do	...do	...do	Do.
56	17	...do	19	2.006	1.493		...do	...do	...do	...do	...do	Do.
57	18	...do	19	2.05	1.49		...do	...do	...do	...do	...do	Do.
58	21	...do	19	1.963	1.4		...do	...do	...do	...do	...do	Do.
59	22	...do	19	1.773	1.31		...do	...do	...do	...do	...do	Do.
60	23	...do	19	1.96	1.493	0.615	...do	...do	...do	...do	...do	Do.
61	1	Oct. 21	67	2.035	1.677		...do	...do	...do	...do	...do	Complete.
62	2	...do	67	2.035	1.76	.66	...do	...do	...do	...do	...do	Do.
63	3	...do	67	2.035	1.76	.66	...do	...do	...do	...do	...do	Do.
64	4	...do	67	2.255	1.97	.66	...do	...do	...do	...do	...do	Do.
65	7	...do	67	2.2	2.15	.66	...do	...do	...do	...do	...do	Do.
66	11	...do	67	1.98	1.705	.55	...do	...do	...do	...do	...do	Do.
67	12	...do	67	2.09	1.87	.715	...do	...do	...do	...do	...do	Do.
68	15	...do	67	2.145	1.65	.715	...do	...do	...do	...do	...do	Do.
69	16	...do	67	2.145	1.651	.517	...do	...do	...do	...do	...do	Do.
70	18	...do	67	2.09	1.705	.66	...do	...do	...do	...do	...do	Do.
71	21	...do	67	2.145	1.595	.495	...do	...do	...do	...do	...do	Do.
72	22	...do	67	1.925	1.54		...do	...do	...do	...do	...do	Do.
73	23	...do	67	2.145	1.65	.66	...do	...do	...do	...do	...do	Do.

The Female Upon the Twig: Rate of Growth.

To determine the relative rate of growth of females after attaching to the twigs Table XXIX was compiled from the data obtained in 1913. This shows an increase from attachment on the twigs to the sixty-seventh day of 500 per cent in height and a pronounced increase in length and width. It is evident from this table that nearly all the growth takes place during the first 19 days.

Table XXIX.—*Size of twig-attached females of the terrapin scale after the specified days upon the twigs, Mont Alto, Pa., 1913.*

Date.	Number of specimens.	Period on twig.	Average length.	Average width.	Average height.
		Days.	*Mm.*	*Mm.*	*Mm.*
Aug. 1...	10	(1)	1.542	1.03	0.125
Aug. 7...	3	1	1.600	1.058	.....
Aug. 8...	3	2	1.65	1.141	.....
Aug. 19..	10	4	1.649	1.297	.208
Aug. 20..	10	5	1.619	1.226	.....
Aug. 23..	13	8	1.686	1.177	.....
Aug. 26..	4	11	1.762	1.25	.....
Aug. 29..	8	14	1.887	1.331	.....
Sept. 3...	13	19	1.996	1.592	.615
Oct. 21...	16	67	2.057	1.680	.625

[1] Just attached.

The Female Upon the Twig: Movement After Attaching to the Twigs.

It is very doubtful whether the females ever reattach after the first week's sojourn upon the twigs. During the first few days specimens have been observed to move, but whether or not the proboscis had been inserted into the host is unknown. Efforts were made to determine this, but no data were obtained. However, observations made upon specimens attached to slowly drying twigs indicate that they do not change position after the eleventh day.

The Derm.

With the arching of the dorsum during the first week the flat wax scale which protected the female larva during the migration from leaf to twig scales off; meanwhile the exposed surface thickens and hardens until by the end of the week it is so rigid that it responds to the growth changes by crimping. This hardening and thickening of the dorsum which produces the hard shell-like derm is completed by the twenty-fifth day. The excretion of wax, however, continues and wax flakes can be found attached to the derm up to the time of death.

Honeydew.

The attachment of the females to the twigs marks the beginning of the maximum period of honeydew deposit. If it were not for the deposit at this time the honeydew would be of very little economic

importance. This period of excretion extends to the time of hibernation, but practically all the honeydew is deposited during the first 25 days.

The anal apparatus is specially adapted to the excretion of honeydew. The anal plates, which are situated near the posterior end of the derm, are so hinged at their anterior ends that they can be both elevated and separated. When in this position they expose the anal chamber which lies just below them. This chamber is bounded laterally by the body lobes and connects ventrally with the brood chamber, while a cloacal cavity extends forward, within which there is a retractile spindle-shaped rectum, at the distal extremity of which the anal aperture is located. It is surrounded by a fringe of eight filaments called the anal ring. During repose the rectum occupies the anterior part of the cloacal cavity, and the anal fringe, which is folded into a cylindrical mass, occupies the posterior part. When the scale is not excreting the anal cavity is empty and closed at the top by the lidlike anal plates. Preparatory to excretion the anal plates are elevated and separated; the rectum with its fringe is drawn backward from the cloacal cavity into the anal chamber, from which it is thrust through the opening between the elevated anal plates. Contraction of the muscular walls of the rectum causes the contents to ooze into the basket formed by the filaments of the anal ring, where it forms a bubble which is held in place upon the end of the rectum by the supporting filaments, much as a jewel is held in its setting. When the bubble is fully formed it bursts, hurling the liquid composing it in the form of minute drops to a distance of from 3 to 8 inches. Cohesion between the honeydew and the filaments of the fringe is very slight. As a result no honeydew remains upon the fringe after the bursting of the bubble. The rectum is always withdrawn and the anal cavity closed after each expulsion. The deposit of honeydew from the twig-attached females becomes noticeable in orchards during the first week in August and rapidly increases in amount during the remainder of the month. At Midvale, Pa., in 1913, the deposit was first noticed August 4. It was made by the few advanced females then upon the twigs. The amount excreted reached its maximum on August 23, after which the amount upon the trees remained nearly constant until the first week of September. The sooty fungus which develops upon this honeydew increases in abundance with the increased deposit, and by the end of August its black spores have transformed the transparent honeydew into a sooty paste. By the end of the first week in September the leaves, branches, and fruit are covered by a black film of dried honeydew and spores. In some cases the infestation is so severe that the soil under the tree is coated almost as thickly as the limbs. The deposit

appears at its worst upon varieties that ripen after September 1. A basket of sooty peaches, with two normal peaches for comparison, is shown in figure 16.

Hibernation.

The scales depend for protection during hibernation upon their protective coloration, their hard derm, and their waxy coating. The color, while conspicuous in detached specimens, blends so nicely with the color of the young twigs as to conceal them effectively. The hard derm protects them from birds and insect enemies, and the wax film protects the insect from rain, surface moisture, and scalecides by preventing their passing under the scale.

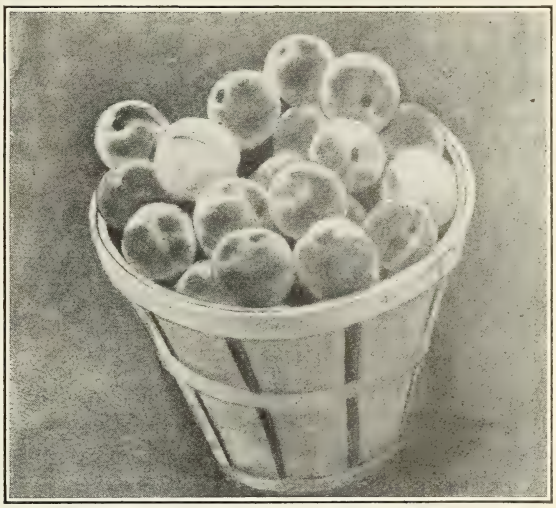


Fig. 16.—A basket of "sooty" peaches with two clean ones for contrast. (Original.)

Size during hibernation.

Eulecanium nigrofasciatum passes the winter as an impregnated female. The following measurements, which were taken from fresh specimens at Mont Alto, Pa., February 24, 1913, are typical for the hibernation period: Length, maximum 2.375 mm., minimum 1.80 mm., average 2.072 mm.; width, maximum 2.28 mm., minimum 1.79 mm., average 2.0308 mm.; height, maximum 1.1 mm., minimum 0.725 mm., average 0.9084 mm.

Position on twigs during hibernation.

This species when on peach locates exclusively upon the last three seasons' growth, and by far the largest number of specimens is found upon the earliest formed wood of the last growing season. (See Pl. III, figs. 1, 2.)

The females in 1912 continued more or less active until November 12, and they remained dormant until April. This made the hibernating period cover about 4½ months.

Mortality during hibernation.

Practically every normal female will pass the hibernation period safely unless some accident happens to the host. Specimens at Mont

Alto, Pa., during the winter of 1912–13 passed this period with a mortality of less than 10 per cent. At Midvale, Pa., during the winter of 1913–14, specimens upon poorly nourished trees had a mortality as high as 54 per cent. Neither birds nor other animals make a noticeable attack during hibernation, but there is a strong parasitic attack upon the young females before hibernation. This was especially noticeable during the first week in September.

DEVELOPMENT OF THE MALE.

Male Larva, Second Instar.

In this instar the elongation of the larva and the secretion of the puparium undoubtedly start immediately after the first molt, but it is usually five or six days before they can be detected. The male increases, as is shown in Table XXX, from an average length of 1.03 mm. to an average length of about 1.706 mm., and in width from an average of 0.421 mm. to an average of about 0.830 mm. There is also an appreciable increase in height.

Table XXX.—*Average measurements of the male terrapin scale in the second instar at various ages between the twenty-fifth and thirty-fourth days, at Mont Alto, Pa.*

Year.	Date emerged.	Age.	Number of specimens.	Average length.	Average width.
		Days.		*Mm.*	*Mm.*
1912	Aug. 9	25	1	1.031	0.468
1912	...do.....	26	2	1.218	.421
1913	June 24	30	14	1.628	.830
1912	Aug. 9	31	4	1.579	.642
1913	June 26	32	13	1.661	.809
1913	June 24	33	13	1.621	.813
1913	...do.....	34	8	1.706	.777

In 1912 the instar extended to the fortieth day, but practically all males had shrunk in preparation for the second molt by the thirty-fifth day.

The following table compares the measurements of 54 females in the second instar with 48 males of the same rearing, and shows that the females average 0.168 mm. wider and 0.111 mm. shorter than the males.

Table XXXI.—*Comparative measurements of male and female larvæ of the terrapin scale during the second instar, Mont Alto, Pa.*

Age.	Date emerged.	Number males.	Length of males.	Width of males.	Number of females.	Length of females.	Width of females.
Days.			*Mm.*	*Mm.*		*Mm.*	*Mm.*
30	June 24	14	1.628	0.830	7	1.507	0.982
32	June 26	13	1.661	.809	16	1.506	.937
33	June 24	13	1.621	.813	20	1.587	.978
34	...do.....	8	1.706	.777	11	1.575	1.012
	Total....	48	.....	.....	54	.....	.....
	Average.	.....	1.654	.807	.....	1.543	.975

The male larva stops growth one day before the second molt, after which it shrinks and tends to assume a cylindrical form. The amount of this shrinkage, as is shown, averages 0.16 mm. in length and about 0.137 mm. in width. As a result of this shrinkage the edges of the puparium extend beyond the larva like the eaves of a roof.

TABLE XXXII.—*Shrinkage of 13 male larvæ of the terrapin scale during the last day of the second instar, 1913.*

	July 27.	July 28.	Difference.
	Mm.	*Mm.*	*Mm.*
Average length	2.17	2.01	0.16
Average width	1.075	.9375	.1375

The author's observations indicate that both sexes make the second molt at the same time and that they spend the same number of days in the second instar.

THE PUPARIUM.

The puparium is a transparent protective covering under which the male passes the third, fourth, and part of the fifth instar. It is secreted by dorsal wax pores during the second instar (Pl. II, *a*, *e*), and has the same dimensions as the full-grown larva, but owing to the shrinking of the larva the puparium at the end of the second instar is the larger. This structure is held in place by elastic bands which extend from points upon its edges to the leaf below. The largest of these is attached directly in front of the head. The ornamentation of the puparium consists of 2 longitudinal lines, 3 cross-lines, and a spear-shaped notch, which coincide in position at the time of its secretion with the anal plates and anal cleft of the larva. The longitudinal lines extend from the anterior end of the anal notch in mildly diverging curves anteriorly to a termination on the lateral edges near the position of the eye-spots of the larva. The cross lines, which are broken, are located at the middle and on the anterior and posterior thirds.

In this species the puparium is always placed upon the underside of the leaf (Pl. III, fig. 3) and never upon the twigs. In this it differs from *Eulecanium corni* Bouché, which frequently has puparia upon the twigs. Twenty-four puparia taken at Mont Alto, Pa., during 1912, had the following sizes: Length, maximum 1.725 mm., minimum 1.443 mm., average 1.641 mm.; width, maximum 0.825 mm., minimum 0.54 mm., average 0.707 mm. The puparia of 1913 in the same orchard were slightly larger; 13, measured July 28, averaged in length 1.706 mm. and in width 0.778 mm.

Second Molt of the Male.

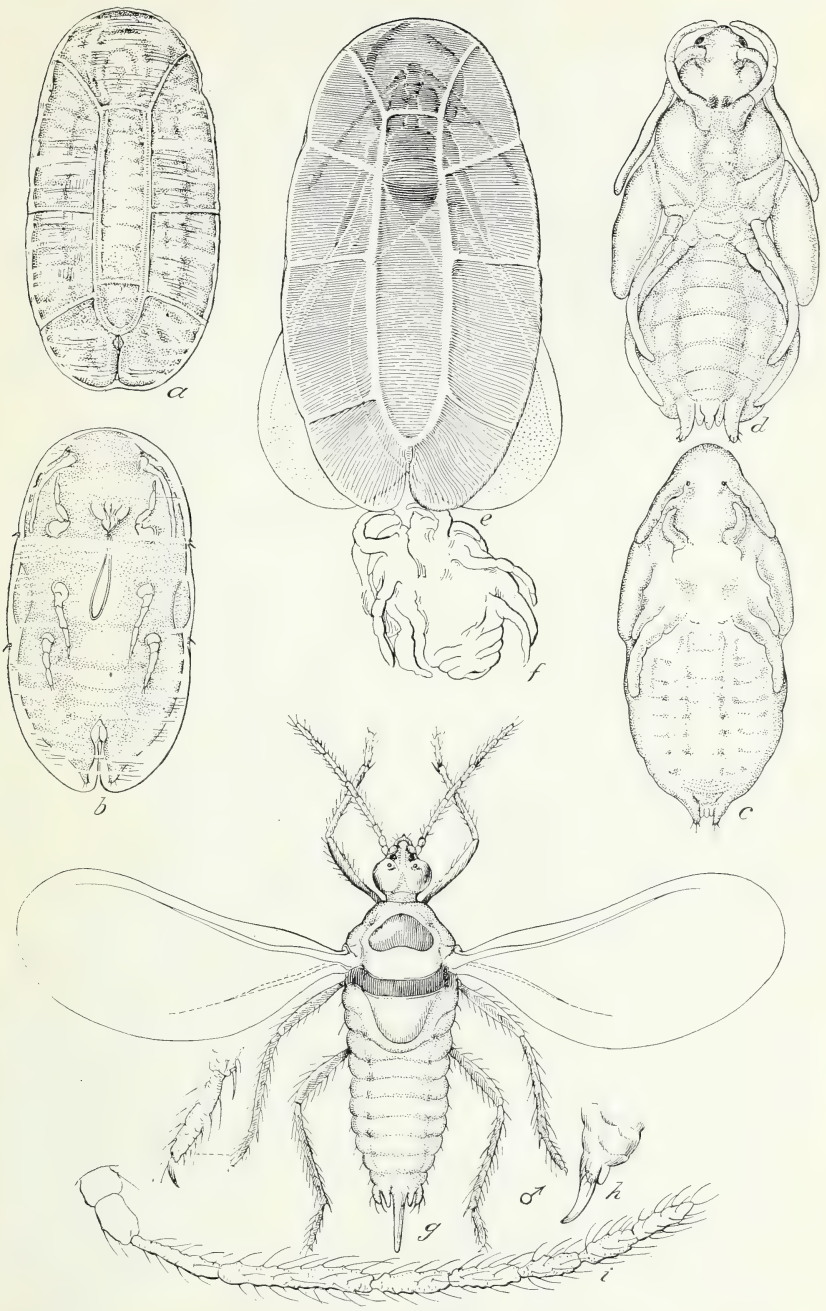
In 1912 the second molt was made by orchard larvæ from the thirty-eighth to the forty-third day, with its maximum upon the forty-first day, after emergence from the brood chamber. In 1913, with a more favorable season, this molt was made by orchard larvæ upon the thirty-sixth day. Since the larvæ entered the second instar upon the eighteenth day, they averaged 18 days in the second instar. Two rearings were made in 1913, the first from larvæ that emerged June 24 and the second from larvæ that emerged June 26. The former made their maximum daily molt for both sexes upon the thirty-seventh day, the latter upon the thirty-fourth day.

When the male larva shrinks at the end of the second instar the larval skin retains its original shape and position (Pl. II, *b*). This leaves the larva nearly free within. At this time a decided metamorphosis begins. The original legs, antennæ, and mouth-parts disappear and the anal lobes, which in the second instar are one-half as wide as the body and extend caudad beyond the anal plates (Pl. II, *a*), now shrink to short, narrow projections which extend only slightly beyond the anal plates. As a result of this change in the anal lobes the anal crease disappears and the anal apparatus assumes again its original position on the caudal margin. During this metamorphosis the hard portions of the mouth-parts remain attached to the larval skin and disappear at the second molt, after which all trace of the mouth-parts is lost. In the act of molting the larval skin is ruptured by contortions of the larva along the middorsal line, and in a few minutes it is worked downward and backward and is expelled at the caudad margin of the puparium, where it usually remains for a few days clamped under the puparium.

The Prepupa.

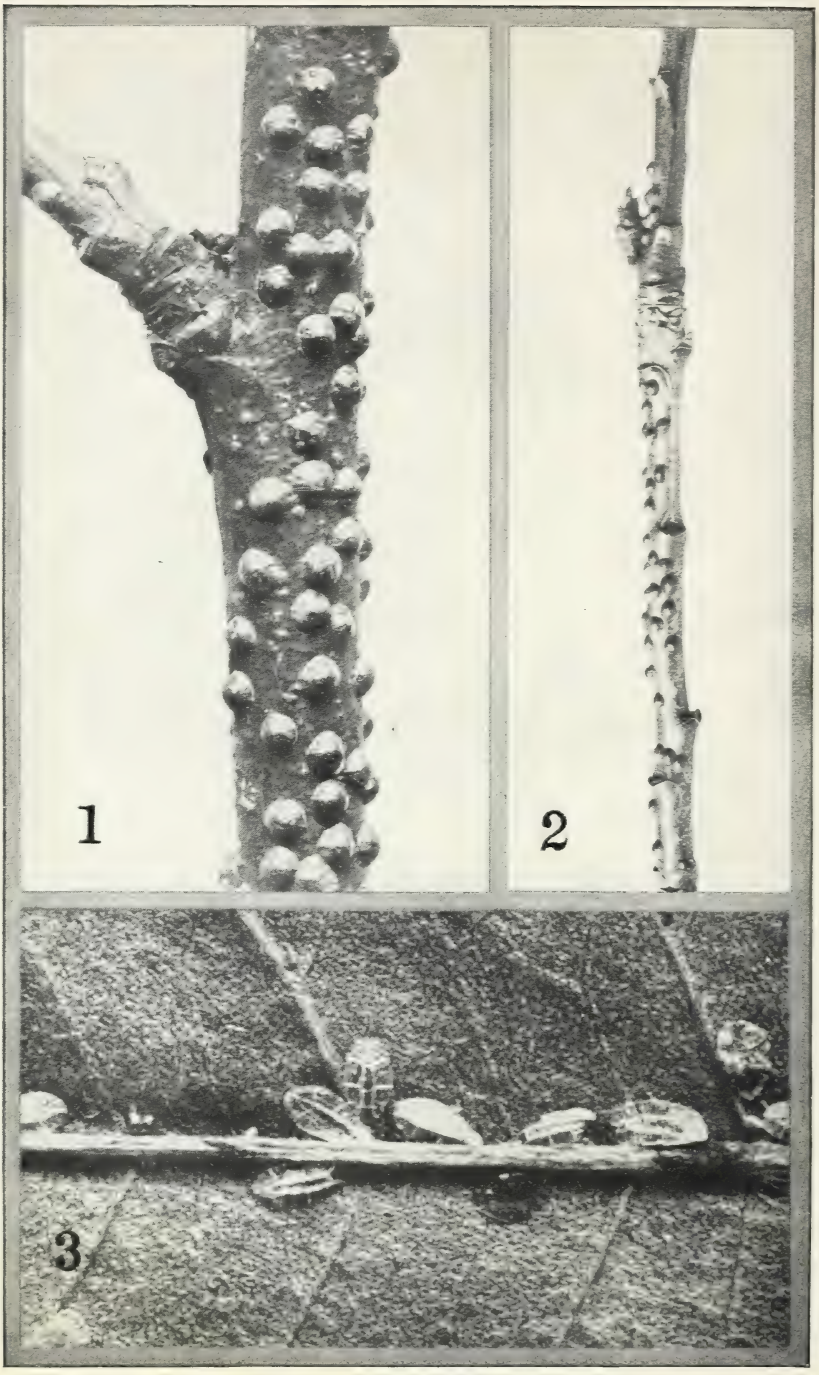
The prepupal instar is characterized by a rapid metamorphosis, which, however, actually starts before the casting of the second molt skin. The plump anal lobes of the first and second instars shrink, and the characteristic anal plates (Pl. II, *a*) are lacking. The most evident characters at the beginning of the instar are the wing-pads and the pointed anal lobes.

The prepupal period covers but 2 days, yet the metamorphosis is so rapid that decided changes occur. The wing-pads expand to their full size; the antennal sheaths expand from buds to nearly one-half of their final length, and the leg sheaths, which at the beginning of the instar were indicated by imaginal buds, become one-fourth developed. The metamorphosis of the anal region continues throughout this instar and at its end all trace of the conspicuous anal plates is lost. In their place there now project from the caudal extremity two



THE TERRAPIN SCALE.

a, The second instar under the puparium; *b*, same, shrinking in the last day of the second instar; *c*, prepupa; *d*, pupa; *e*, imago before emergence; *f*, pupa case clamped under the puparium; *g*, imago at twigward migration; *h*, lateral view of caudal extremity; *i*, enlarged antenna. All much enlarged. (Original.)



THE TERRAPIN SCALE.

FIG. 1.—Appearance of the scale on peach twig during winter; somewhat enlarged. FIG. 2.—Same, about natural size. FIG. 3.—Male puparia along midrib of peach leaf; considerably enlarged. (Original.)

fleshy lobes, between which are the sheaths of the copulatory apparatus. (Pl. II, *c*.) The ventral eyes are represented at the end of this instar by two brown spots.

This instar is quite constant in its length, being almost invariably 2 days. Table XXXIII gives data upon 18 males from the rearing of June 24, 1913. The average length was 2 days.

TABLE XXXIII.—*Average duration of the prepupal instar for 18 specimens of the terrapin scale, Mont Alto, Pa., 1913.*

No.	Date of second molt.	Date of third molt.	Time in prepupa.	No.	Date of second molt.	Date of third molt.	Time in prepupa.
			Days.				*Days.*
1	July 31	Aug. 2	2	11	July 31	Aug. 3	3
2	Aug. 4	Aug. 6	2	12	July 30	Aug. 1	2
3	July 31	Aug. 2	2	13	July 31	...do	1
4	July 30	Aug. 1	2	14	July 29	July 31	2
5	...do	...do	2	15	Aug. 1	Aug. 3	2
6	...do	...do	2	16	...do	...do	2
7	...do	Aug. 2	2	17	Aug. 5	Aug. 7	2
8	...do	Aug. 1	2	18	Aug. 4	Aug. 6	2
9	Aug. 1	Aug. 3	2				
10	July 31	Aug. 2	2	Average			2

Larvæ that emerge upon the same day may vary as much as 10 days in the time required for them to reach the prepupa. The normal time of entering this instar, however, is clearly defined for most individuals. One-half of the males in any rearing will ordinarily become prepupæ upon the same date. The normal time for entering this instar in the region about Mont Alto, Pa., is upon the thirty-eighth day after emerging from under the parent scale.

Prepupæ were abundant in the orchard at Mont Alto, Pa., in 1912, from August 8 to August 20. They were present in largest numbers about August 12; after this they became gradually less abundant until August 25. After August 25 they were very scarce. At Midvale, Pa., in 1913, the first prepupæ were taken July 18. At Mont Alto, Pa., in 1913, the first prepupæ were taken July 24. This is 5 days earlier than they appeared at Mont Alto the preceding year.

Since both sexes made the second molt at the same age, and since the females migrate twigward upon the second day after this molt, it happens that the twigward migration of the females coincides with the prepupal instar of the male. In 1912 the first returned females—6 specimens in all—were taken July 29. While there were undoubtedly as many prepupæ as returned females at this time upon the trees, none was found. By August 2 the number of returned females had greatly increased and, upon this date, the first prepupæ of the season were taken.

There was a difference in 1913 of 6 days in the appearance of prepupæ at the Wertz and in the Newcomer orchards. This was due to the difference in the localities. The Wertz orchard has a strong

westward slope and is located at an altitude of 1,100 feet, with a mountain crest extending 1,000 feet above it. There is consequently a good air drainage and a partial exclusion of the sun's rays during the forenoon. The Newcomer orchard, upon the other hand, is located upon a slight knoll, with relatively level surroundings. Its altitude is less than 900 feet. Consequently the air drainage is not good and the sun's rays are unobstructed.

Four prepupæ were measured in 1912, with the following results: Length, maximum 1.29 mm., minimum 1.08 mm., average, 1.208 mm.; width, maximum, 0. 618 mm., minimum, 0. 562 mm., average, 0.587 mm. On April 28, 1913, 8 specimens gave the following measurements: Length, maximum 1.420 mm., minimum 1.25 mm., average 1.33 mm; width, maximum 0. 6 mm., minimum 0. 525 mm., average 0.559 mm.

Third Molt.

The prepupa starts the third molt by a series of convulsive movements which cause the dorsal skin to split over the thoracic region. The skin is loosened and removed almost entirely by extending and contracting the abdomen. The extension thrusts cause a tension upon the ventral part of the molt skin which draws the head downward and under. This causes the dorsal thorax to protrude through the split in the molt skin. This tension increases with each thrust of the abdomen, so that the head is drawn farther and farther downward and backward until it finally slips free from the skin. The larva then assumes its regular position. In stripping the molt skin from the legs and antennæ the thrusting movements of the abdomen are aided by the puparium, which, owing to its attachment with elastic bands, yields to the molting movements and serves as a clamp to hold the skin in place while the abdomen contracts for the next thrust. The thrusting movements of the abdomen usually cease before the skin is completely expelled from under the puparium. Because of this the cast skins are mostly found clamped under the posterior end of the puparium.

The duration of this molt varies with the temperature at the time of molting and also with the vigor of the specimen. The molt usually starts in the forenoon with the resumption of the daily activity. The average time for this molt is less than an hour. Upon days when the temperature reaches 70° F. before 9 a. m., practically all the molts for the day will be completed by 10 a. m. At low temperatures many specimens die without completing it. Some specimens kept in the laboratory where the temperature did not rise above 70° F. required 18 hours for this molt. They started molting about 4 p. m. and became dormant before completing it. These molts were completed the following day.

The Pupa.

The pupal instar is one of development. In it the rudimental structures of the preceding instar reach their full development. The leg sheaths are mere tubes at the beginning of the instar; at the end they contain the matured legs. The wing sheaths have a similar history, being at first transparent bags, which develop gradually until the last third of the instar, when the wings fold and the characteristic fleshy color appears. The pupa (Pl. II, *d*) has a pale flesh color with chitinized areas upon the head and anal region. There is also a crescent-shaped spot and a transverse band of a bright flesh color. The antennæ and legs are at first ventral, but they elongate and finally appear prominently in the dorsal view.

TIME IN PUPA.

The pupal instar varies in length, occupying from 4 to 11 days, and averages about 6 days in favorable weather. Those individuals that spend only 4 days in this instar have invariably been delayed as prepupæ. It is very exceptional for a male to pass 8 days in the pupa, even when weather conditions are unfavorable. When conditions are such that the pupæ require over 9 days, there is a heavy mortality. Many die, and those that enter the adult stage mostly die without leaving the protection of the puparium.

In both 1912 and 1913 rearings were made to determine the length of the pupal period under varying conditions. Observations made upon the specimens in the orchard showed that most of the specimens remained in the pupa 6 days. A brood that emerged July 22, 1912—that is, approximately a month after the height of the normal emergence—was retarded 6 days by unfavorable conditions. Thirteen males passed successfully through the pupal stage and gave an average of 8.15 days in the pupal instar.

The average mean temperature for July, August, and September, 1912, was 71.5° F.

A brood that emerged June 24, 1913—that is, appproximately at the height of emergence—passed through the larval instars in a normal manner, and the imagos left the puparia upon the forty-sixth day. These specimens were slightly retarded, owing to their removal while in prepupa from the orchard to the laboratory. Fourteen of these specimens passed through the pupal instar in a normal manner. They gave an average of 6.2 days for the pupal instar. The fraction of a day in excess of 6 days is small and is clearly due to the unfavorable environment of the laboratory. Table XXXIV gives the individual record of these 14 males. The average mean temperature for June, July, and August, 1913, was 73.4° F.

TABLE XXXIV.—*Length of the pupal instar of the terrapin scale for larvæ that emerged June 24, 1913, Mont Alto, Pa.—Conditions favorable.*

No.	Date entered.	Date left.	Pupal stage.	No.	Date entered.	Date left.	Pupal stage.
			Days.				*Days.*
1	Aug. 2	Aug. 10	8	9	Aug. 2	Aug. 9	7
2	...do	Aug. 8	6	10	Aug. 1	Aug. 8	7
3	Aug. 1	...do	7	11	July 31	Aug. 5	5
4	...do	Aug. 7	6	12	...do	Aug. 6	6
5	...do	Aug. 8	7	13	Aug. 3	Aug. 8	5
6	Aug. 2	...do	6	14	Aug. 1	Aug. 7	6
7	Aug. 1	Aug. 5	4				
8	Aug. 3	Aug. 10	7	Average			6.2

APPEARANCE OF PUPÆ IN THE ORCHARD.

Pupæ appear in the orchard upon the second day after the females start migrating to the twigs, and they are most abundant about the sixth day after the maximum daily migration.

At Mont Alto, Pa., 80 per cent or more of the males pass through the pupal state during the first half of August.

SIZE OF PUPÆ.

The pupæ are slightly smaller than the prepupæ, but owing to the great size of the wing-pads the pupæ average slightly wider.

Table XXXV gives measurements for 20 specimens, the first 10 of which were from 1912 and the remainder from 1913. The sizes are quite uniform for the two seasons and average 1.248 mm. long and 0.5918 mm. wide. A comparison of the prepupal and pupal measurements from the same individuals shows an average decrease in length of 0.09 mm. and an increase of 0.03 mm. in width in passing into the pupal instar.

TABLE XXXV.—*Measurements of 20 mature pupæ of the terrapin scale, Mont Alto, Pa., 1912 and 1913.*

No.	Length.	Width.	No.	Length.	Width.	No.	Length.	Width.
	Mm.	*Mm.*		*Mm.*	*Mm.*		*Mm.*	*Mm.*
1	1.2250	0.55	9	1.1000	0.600	16	1.250	0.650
2	1.3375	.575	10	1.2500	.625	17	1.175	.575
3	1.2750	.550	11	1.325	.625	18	1.275	.650
4	1.3000	.600	12	1.250	.475	19	1.250	.625
5	1.3000	.550	13	1.250	.650	20	1.250	.600
6	1.2500	.600	14	1.250	.550			
7	1.2500	.562	15	1.200	.600	Average	1.2481	.5918
8	1.2000	.625						

FOURTH MOLT.

The fourth molt, like the third, usually starts in the morning when the temperature rises to about 70° F. The first indication that a molt is about to start is a series of convulsive movements. These cause the thin pupa case to split along the anterior third of the middorsal line. As these movements continue the dorsal thorax pro-

trudes more and more through this slit and the head is forced downward. Before the head escapes the anterior legs are withdrawn from their sheaths. These are the first appendages to become free. They push the case downward until the head is free. After this they force the case backward under the body. The antennal sheaths cling tightly to the antennæ and have to be stripped free from them. The middle and posterior legs take no active part in the molt, but lie motionless along the edges of the abdomen. The antennal sheaths are the last parts of the case to be shed. After the head escapes from the case it presses against the anterior end of the puparium, which serves as a fulcrum in forcing the adult free from the pupa case. Pupæ that escape by accident or are removed from under the puparium are unable to complete the molt. They continue the effort for about 24 hours and then die. In the case of weak specimens the impulse to molt often ceases before the tips of the antennæ are free. After this molt the pupal case is usually found lightly clamped under the posterior edge of the puparium. (See Pl. II, *f*.)

This molt ordinarily requires about 2 minutes for specimens at temperatures above 70° F., but at a temperature of 66° F. the time required is 5 minutes. This molt should take place about the forty-seventh day, but it is frequently delayed. For example, part of a brood that emerged August 9, 1912, was removed from the trees when in pupa. They were placed in the laboratory late in September, away from heat and sunlight, and under these conditions many of the specimens died. The remainder were abnormal and did not molt until the fifty-fifth day, or 8 days after the natural time. It was evident that a slightly longer delay would have resulted in the death of all the specimens in the pupa or during the molt.

The Adult Male.

The fourth molt, like the third, is made under the puparium. The young imago at first has soft and folded wings, but these soon assume their natural shape. Several hours, however, are required for them to harden and to become fully colored. After expanding they protrude slightly from under the posterior end of the puparium and serve as a means of identifying this stage. The time spent under the puparium varies from a few hours to 4 days. The normal time for the male to remain under the puparium is from 1 to 2 days. The male regularly enters the imago in the forenoon of one day and emerges during the afternoon of the following day, but there are well-defined exceptions to this. If favorable weather has so accelerated the growth as to shorten the preceding instars, the imago tends to remain under the puparium until the regular time for emerging, but when the early instars are lengthened by unfavorable weather the imago emerges in less than 2 days.

In Table XXXVI are recorded data from 14 males that emerged late in the season of 1912. They had the fourth molt delayed to the fiftieth day and give an average of 1.36 days as the time spent under the puparium. Specimen No. 3 partly escaped from under the puparium during the fourth molt. It remained in this position for 4 hours and then emerged and started to leave the leaf.

TABLE XXXVI.—*Emergence of 14 males of the terrapin scale from a brood that made the fourth molt upon the fiftieth day, Mont Alto, Pa., 1912.*

No.	Fourth molt.		Emergence.		Time spent under puparium.
	Date.	Time.	Date.	Time.	
					Days. Hrs.
1	Sept. 5	8.40 a. m.	Sept. 6	8.40 a. m.	1 0
2	Sept. 9	10 a. m.	Sept. 10	10 a. m.	1 0
3	Sept. 11	6 a. m.	Sept. 11	10 a. m.	4
4	...do...	6 a. m.	Sept. 14	6 a. m.	3 0
5	Sept. 10	2 p. m.	Sept. 12	6 a. m.	1 16
6	Sept. 12	6 a. m.	...do...	6 p. m.	12
7	Sept. 11	12 m.	Sept. 14	9 a. m.	2 21
8	Sept. 12	1 p. m.	Sept. 13	6 a. m.	1 17
9	Sept. 11	2 p. m.	...do...	6 a. m.	1 16
10	Sept. 12	6 p. m.	...do...	6 a. m.	12
11	Sept. 11	12 m.	Sept. 12	6 a. m.	18
12	...do...	12 m.	...do...	6 a. m.	18
13	Sept. 10	9 a. m.	...do...	6 a. m.	1 21
14	...do...	3 p. m.	...do...	6 a. m.	1 15
Average					1 9.07

In Table XXXVII are recorded data from 12 imagos that emerged from the brood chamber June 24 and made the fourth molt upon the forty-fifth day. They were thus normal in development. They give an average of 2 days spent under the puparium. Eight specimens from this same brood were removed from the orchard 7 days before they emerged as imagos and placed upon glass plates in the laboratory. As a result of this treatment they were delayed in the pupal stage and spent only one day under the puparium, a reduction of one-half in the time due to the changed conditions.

TABLE XXXVII.—*Emergence of 12 males of the terrapin scale from a brood that made the fourth molt upon the forty-fifth day, Mont Alto, Pa., 1913*

No.	Date of fourth molt.	Imago emerged.	Time under puparium.	No.	Date of fourth molt.	Imago emerged.	Time under puparium.
			Days.				*Days.*
1	Aug. 10	Aug. 11	1	8	Aug. 10	Aug. 11	1
2	Aug. 8	Aug. 9	1	9	Aug. 8	Aug. 10	2
3	...do...	...do...	1	10	Aug. 7	...do...	3
4	July 7	Aug. 11	4	11	Aug. 5	Aug. 8	3
5	Aug. 8	Aug. 9	1	12	Aug. 8	Aug. 10	2
6	...do...	...do...	1				
7	Aug. 5	...do...	4	Average			2

A comparison of Tables XXXVI and XXXVII shows that the time spent under the puparium by the imago varies from 4 hours to 4 days and that the average time for normal development is 2 days.

Imagos were taken from under puparia in small numbers at Midvale, Pa., on July 27, 1913. These were the earliest specimens taken during the two seasons of observation.

EMERGENCE OF ADULT MALE.

The imago (Pl. II, *g*) usually leaves the puparium about the forty-ninth day. In 1912 the early part of the season was favorable and the imagos emerged upon the forty-ninth day, but later in the season males reared from larvæ that emerged from the brood chamber August 9 did not leave the puparium until the fifty-second day, with several specimens delayed until the fifty-eighth day. In 1913 the males emerged from the forty-third to the fifty-ninth day, with the maximum emergence upon the forty-ninth day.

DESCRIPTION OF ADULT MALE.

Length, exclusive of style, 1 mm.; style 0.15 mm.; caudal lobes 0.075 mm., being one-half as long as the paired lateral appendages; antennæ 0.6 mm.; wing, 0.44 mm. long, 0.3 mm. wide. Light flesh color in general. Head light flesh color; anterior pair of dorsal eyes reddish brown; posterior dorsal eyes similar and one-half as large; ventral pair dark brown and slightly larger than the anterior dorsal pair; antennæ whitish, 8-jointed, joint I short, thick, semiglobular; joint II slightly longer than I, claviform; joint III as long as both I and II, slender and cylindrical; the remaining joints cylindrical and subequal. Collar short cylindrical; prothorax narrow; dorsal mesothorax light flesh color, with a flesh-colored shield-shaped spot above, and terminated posteriorly by a narrow bright band of the same color; metathorax light flesh color. Wing iridescent, surface granulose, false vein through anal third; halteres none; caudal filments none; legs and style light brown.

TWIGWARD MIGRATION OF THE MALE.

The male backs out from under the puparium and at once starts for the twigs. The wings are not ordinarily used in this migration. The insect is attracted by strong light and seems to be guided somewhat in its movements by gravity and possibly also by the scent of the female. The males leave the underside of the leaf and pass down the petiole. When the twig is reached they turn downward and examine the surface carefully as they pass over it. The antennæ are held aloft and nearly motionless, but the anterior tarsi are kept in constant motion, tapping and feeling the surface of the twigs. The males frequently in their search pass to the tips of the twigs, and in such cases they may circle the twig a few times and then return to the base and pass on, but when the illumination is strong they alight upon other twigs and start again in active search. The interval between emerging and starting the active search for the female scales is very brief, being always less than 30 minutes. The male is sexually mature when he emerges. When he approaches a female he taps upon the derm with his anterior legs, usually passing several times around the specimen in doing so, or he may conduct the examination while upon the female's back. During such an

examination the male is often diverted and may move away, but he will return, again and again, before finally abandoning his efforts. Those females that have copulated are indifferent to the male, but females of the same age that have not copulated respond by elevating and distending the anal plates. After a preliminary examination of the dorsal surface of the female the male mounts and takes the copulating position, with the head forward and the body parallel to that of the female. In the act of copulation the abdomen is curved under until the tip is in contact with the anal plates. The act of copulation requires from 2 to 10 seconds, according to the degree of exhaustion of the male. At the end of copulation the male departs and continues his search for additional mates. If by chance he returns a second time to the same female his tappings bring no response. The male is decidedly polygamous and continues copulating with one female after another until he dies of exhaustion. The following observations were made upon a male that left the puparium September 6, 1913:

Emerged from puparium	9.40 a. m.
Discovered first susceptible female and copulated	9.42 a. m.
Discovered second female and copulated	9.44 a. m.
Discovered third female	9.46 a. m.
Discovered fourth female	9.50 a. m.
Discovered fifth female	9.56 a. m.
Died of exhaustion	9 p. m.

At the end of the fifth copulation detailed observations stopped, but the male continued in diligent search for more females. This individual died of exhaustion 12 hours after leaving the puparium.

The active male, when moving naturally upon the host plant, lives less than 24 hours. Almost invariably the male emerges in the forenoon, exhausts himself in copulation during the hottest portion of the day, and dies before midnight. When confined singly in test tubes they live from 1.25 to 2.75 days. Six specimens confined in test tubes gave 2.75 days as the maximum, 1.25 days as the minimum, and 1.625 days as the average longevity.

Summary of Life History of the Male.

The male lives an average of 49 days and passes through 5 instars. In the first two instars it is a vigorous feeder, and accumulates all the energy used during the remainder of its life. The 3 remaining instars are characterized, as a whole, by the absence of functional mouth-parts and by the development of the adult organs.

The length, in favorable weather, and the distinguishing characteristics of the instars are as follows.

The feeding instars: First instar, length 18 days—vegetative; second instar, length 18 days—sexual differentiation.

The nonfeeding instars: Third instar (prepupa), length 2 days—metamorphosis; fourth instar (pupa), length 6 days—development of adult structures; fifth instar (imago) dormant phase, length 2 days—hardening of exo-skeleton; active phase, length 1 day—migration and copulation.

SEASONAL HISTORY.

There is one generation of the terrapin scale annually. This species passes the winter as immature females. At the start of hibernation these are very plump and the ventral part of the abdomen crowds against the surface of the host, so that there is no vacant space beneath the scale, but by the middle of March the abdomen has shrunken until there is a dome-shaped cavity beneath it. When the spring growth starts the specimens become plump again and the space beneath the scale disappears. Most of the specimens reach maturity during the middle of June and begin at once to produce young. The majority of the scales reproduce for a period of about one month. but an occasional female may continue actively reproducing for as long as 3½ months. On the second day after the first young are born they begin to emerge from the brood chamber of the parent, mostly through the anal cleft. During the first 5 weeks there is a heavy migration of larvæ to the leaves. This migration reaches its maximum during the first week of emergence. It then gradually declines, until by the end of the fifth week it amounts to less than 5 per cent of the maximum emergence. (See figs. 2 and 4.) At the beginning of the sixth week after the appearance of the first young the female larvæ start migrating from leaf to twig. By the end of the seventh week the females are ready for copulation and the males migrate to the twigs. Copulation occurs at this time and the males die at once, but the females start upon a period of rapid growth, during which they excrete a vast amount of honeydew, which is responsible for most of the injury caused by this scale. After 2 or 3 weeks of extreme activity their growth gradually slackens, but it continues until cold weather forces the partly mature females into hibernation, after which they remain dormant until the following spring, dying about midsummer after the production of young.

MORTALITY.

There is more or less mortality at all seasons of the year. Ordinarily there seems to be comparatively little due to winterkilling, though at times this may be considerable. The amount of winterkilling depends mainly upon the vigor of the host plant and upon the severity of the winter. During 1912-13, upon well-nourished trees, the mortality from this source was not more than 5 per cent of the hibernating scales. During 1913–14, however, scales upon trees of low vitality had a mortality as high as 40 per cent.

The females during the spring development are sometimes heavily attacked by hymenopterous parasites, especially species of the genus Coccophagus. At the start of reproduction the larvæ of the coccinellid *Hyperaspis binotata* Say (fig. 17) enter the brood chambers and attack the lecanium larvæ, while later the maturing larvæ of this beetle, in attempting to enter the brood chambers, dislodge many of the gravid females, thus destroying at once both the female and the unborn young. (See fig. 18.)

Cold, wet weather at the time of reproduction causes many larvæ to die in the brood chamber. These frequently clog the exit and prevent the egress of the remainder of the brood. This condition was especially noticeable in the season of 1912, when owing to protracted rain 5 per cent of the gravid scales were affected in this way.

During the leafward migration most of the young succeed in reaching the leaves, and the loss at this period is due mainly to drowning by sudden rains and to the dropping of larvæ from dead twigs. During the leaf phase the larvæ are often heavily attacked by predatory enemies, but the female larvæ are practically free from parasitic attack, and the males are but slightly attacked. However, after returning to the twigs the females are subject, at times, to a heavy parasitic attack which may cause a mortality as high as 20 per cent. They are also subject to attack at this time by a pyralid moth, *Laetilia coccidivora* Comst. In conclusion it may be said that the mortality from weather conditions throughout the year is not more than 50 per cent, and that in favorable seasons it is almost negligible.

ATTENDANTS.

The terrapin scale excretes a honeydew which is very attractive to ants, and during the time in which it is being deposited all the species of ants in the vicinity will be found working upon it, while at other seasons no ants will be about. In the early spring, when the fruit buds are about to burst into bloom, considerable honeydew is excreted and ants are then actively working, but during the period of reproduction very few ants appear. When, however, the twigward migration of the females starts, the ants return and remain in almost constant attendance until the scale hibernates. There is no species of ant that habitually attends this scale, but most of the orchard ants feast upon its bounties. Only slight benefit to the scale results from the attendance of the ants. Some of them are pugnacious and undoubtedly tend to ward off predators and to frighten away and confuse parasites.

The following four species taken at Mont Alto, Pa., attending this scale were identified by Dr. W. M. Wheeler:

Formica truncicola Nyl. subsp. *integra* Nyl.
Formica fusca L. var. *subsericea* Say.
Lasius niger L. var. *americanus* Emery.
Prenolepis imparis Say.

PREDACEOUS ENEMIES.

At Mont Alto, Pa., in 1912, the lacewing fly *Chrysopa nigricornis* Burm. made an attack during the twigward migration which was unimportant, although it continued until the larvæ migrated to the twigs. This species was reported in 1893 by Mary E. Murtfeldt as actively attacking the larvæ of this lecanium.

Larvæ of *Hemerobius stigmaterus* Fitch were present in 1912 in considerable numbers and the result of their attack was quite noticeable.

The predaceous pyralid *Laetilia coccidivora* Comst. was present in 1913, and its larvæ made a very vigorous attack. The eggs were placed singly among the scales upon infested twigs, apparently during the first half of June, and hatched in about 6 days. The larva is greenish black, with a black, slightly bilobed head, and feeds within a delicate silken tube which it constructs from scale to scale as it advances along the twig. It first attacks the gravid females, and hundreds of their empty derms can often be seen clinging to one another and to the silken tubes upon trees where it has fed. When the larva reaches its full development it spins a cocoon within the silken tube, usually near the axil of a bud or at the base of a fruit spur. *L. coccidivora*, at Midvale, Pa., requires about 10 days to pass through the pupal stage. The imagos emerged from their cocoons during August and deposited their eggs upon the twigs among the young scales, which were at that time migrating to the twigs. The larvæ of this second brood made a vigorous attack upon the young females. This predator is aggressive and under favorable conditions can undoubtedly control this scale. The author observed its work during the season of 1913, in the orchard of Mr. A. Newcomer, near Midvale, Pa. It was, however, heavily parasitized, and so made very little impression upon its host. Two species of parasites were reared in abundance from this pyralid at Midvale, Pa. They were *Mesostenus thoracicus* Cress. and an undescribed species of Habrobracon.

The predatory bug *Camptobrochis nebulosus* Uhl., although not found at Mont Alto, Pa., was reported by Mary E. Murtfeldt as preying upon the active larvæ of this lecanium at Kirkwood, Mo., in 1893.

Species of Coccinellidæ of the genus Hyperaspis are undoubtedly the most efficient agents in the control of this lecanium. Miss Murtfeldt, in reporting upon *Hyperaspis signata* for 1893, says: "The flocculent larvæ of this coccinellid were very numerous and active among swarming larvæ of *L. nigrofasciatum* but were not found upon any other coccid or aphis during the season."

Mr. A. B. Gahan, in Maryland Agricultural Experiment Station Bulletin 149, mentions the attack by ladybirds and says: "* * * the species most commonly observed being the twice-stabbed lady-

bird, *Chilocorus bivulnerus.*" The writer has occasionally taken the adults of this species, which is scarce about Mont Alto, Pa., upon trees infested with the terrapin scale, but has never observed either it or its larvæ preying upon this scale.

FIG. 17.—A predaceous enemy of the terrapin scale, *Hyperaspis binotata*. Much enlarged. (Original.)

At Mont Alto, Pa., there was, in 1912 and 1913, a heavy and effective attack by *Hyperaspis binotata* Say. This ladybird was taken abundantly in the orchard of D. M. Wertz in 1912 and was very abundant there and in adjacent orchards during the following year. It was also taken in considerable numbers during 1913 at the Newcomer orchard near Midvale, Pa. This ladybird worked so effectively at Mont Alto, Pa., as nearly to exterminate a very severe infestation. *H. binotata* (fig. 17) differs somewhat from the common species of ladybirds, both in its habits and life history. The adult beetles hibernate under bark and in rubbish and become active in early spring. They feed upon

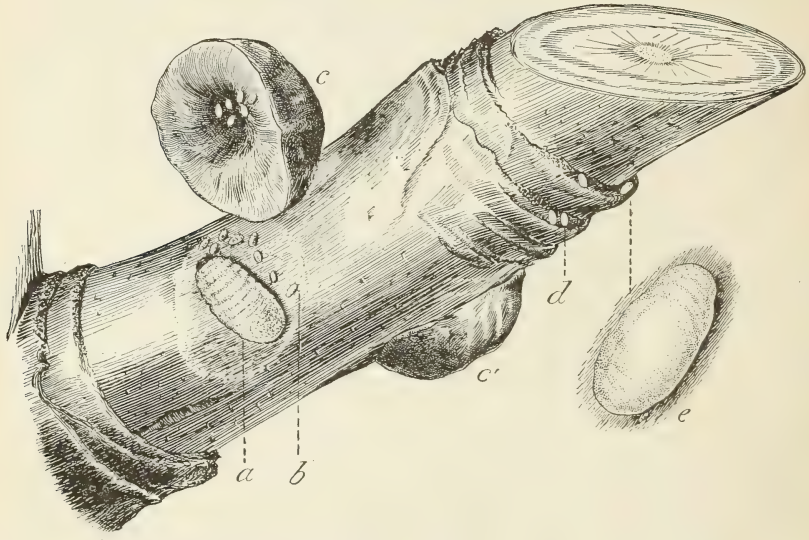


FIG. 18.—Eggs and a second-instar larva of *Hyperaspis binotata* as it appears under a displaced scale: *a*, Second instar as disclosed by displacing the host; *b*, larvæ of the terrapin scale; *c*, a displaced scale; *d*, eggs of the predatory beetle *Hyperaspis binotata* in situ; *e*, egg, highly magnified. All much enlarged. (Original.)

honeydew and upon aphides during the early part of the season but are unable to attack the lecanium in the spring because of its hard derm. They feed upon it readily when the derm is crushed.

The eggs, which are a salmon color, are deposited singly upon the twigs, a favorite place being upon the ringlike scars that mark the limit of the seasonal growth. (Fig. 18, *d*, *e*.) The eggs are too small to be seen readily by the unaided eye. They commence to hatch about the middle of May and the young seek the mature scales and enter their brood chambers by way of the anal cleft. When once within the brood chambers they prey upon the newborn young. The ladybird larvæ make their first molt within this brood chamber and continue to feed until the end of the second instar; by this time the Hyperaspis larvæ are so large that they crowd the brood chamber and often displace their host. Finally the larvæ leave the host and make the second molt, usually at the base of a fruit spur, and then attack other scales, which they do by forcing their heads under the margin and displacing them. In this manner they continue through the third and fourth instars, each larva destroying many gravid scales. When all the gravid females are destroyed the Hyperaspis larvæ, which are then mostly in the fourth instar (fig. 19), migrate to the leaves and continue their feeding upon such of the larvæ as have reached the leaves. Afterwards the ladybird passes the pupal stage in a pupa case attached to the leaves or to the twigs, and sometimes in cavities under the bark. Most of the hibernating beetles die before the first brood emerges from the pupa.

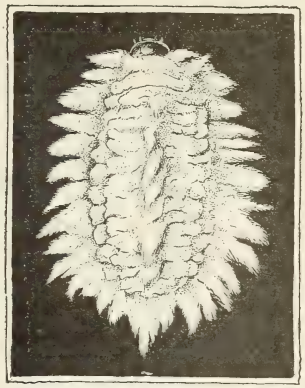


FIG. 19.—The fourth-instar larva of *Hyperaspis binotata* as it appears when attacking the larvæ of the terrapin scale. Much enlarged. (Original.)

PARASITES.

The terrapin scale is heavily parasitized, and this parasitism is mostly confined to the female, though the male is slightly attacked. The first and second instars are very free from parasites, but a heavy attack starts soon after the young females have attached to the twigs. This attack increases in violence until checked by the approach of winter. Most of the parasites pass the winter within the host and emerge early in the season to make a new attack, which reaches its maximum just before the scales begin producing young.

Coccophagus lecanii Fitch was the most abundant species reared in 1912, but *C. cognatus* Howard was also abundant, especially in the fall. In 1913 *C. lecanii* Fitch was rare. In its place *C. cognatus*

appeared in large numbers and attacked the developing females in the spring. That which was apparently the first brood emerged from the hosts about June 30. This infestation was very noticeable owing to the excessive blackening of the scales, as from 20 to 50 per cent of the scales were killed. Later this same species made an attack upon the male larvæ when in the second instar, and in some instances 5 per cent of the males were destroyed. At Ledy Station, Pa., and at Midvale, Pa., this species made a heavy attack in the fall, but at Mont Alto, Pa., it was scarce, owing to the almost complete destruction of the host by *Hyperaspis binotata.*

Aphycus stomachosus Gir. was the most abundant parasite in 1913, being more numerous than *C. cognatus.* It was reared in greatest numbers from the nearly mature females in the early part of June, but it was also taken in large numbers in the orchards during the first half of September. *Aphycus johnsonii* Howard was reared in small numbers from both *Eulecanum nigrofasciatum* Pergande and *E. corni* Bouché at Mont Alto, Pa., but the last-named species seemed to prefer *L. corni* as a host.

Besides the foregoing parasites, *Blastothrix sericae* Dalman was reared from *E. nigrofasciatum* in 1912, as well as numerous specimens of a new genus of Encyrtidæ.

A number of specimens of *Prospalta* sp. were taken from the parasite cages during the season of 1912, but these may have come from armored scales that were introduced by accident.

The records of this bureau contain references to the following species as parasites of *Eulecanium nigrofasciatum*:

Coccophagus ater How.
cognatus How.
lecanii Fitch.
cinguliventris Gir.
longifasciatus How.
flavoscutellum Ashm.
fraternus How.
Aphycus annulipes Ashm.
johnsoni How.
stomachosus Gir.
Anagyrus nubilipennis Gir.
Eunotus lividus Ashm.
Pachyneuron altiscuta How. (secondary).
Prospalta aurantii How.
Chiloneurus albicornis How.
Blastothrix sericea Dalm.
Comys fusca How.

SOOTY MOLDS.

Eulecanium nigrofasciatum does most of its damage to the peach through its mold-infested honeydew, which is deposited in varying amounts throughout the entire season. While this honeydew is objectionable, it would cause very little damage were it not for the sooty molds which grow abundantly on the leaves, twigs, and fruit and on the soil beneath the trees when these are coated with the honeydew. This honeydew becomes noticeable only at three times during the year. A slight deposit from the maturing females appears in

April and May, and another in July from the leaf-attached larvæ; but neither of these deposits is sufficient to do much damage. The really important deposit starts about August 10, at the time when the females attach to the twigs, and continues until the approach of cold weather. The amount of sooty mold produced is limited apparently only by the amount of honeydew excreted. The mold becomes noticeable during the first week in July as black streaks which first appear in the depressions on the upper surface of the leaves. It gradually increases in amount until the middle of August, and from this time until the middle of September the increase is very rapid. The infestation is at its worst about the middle of September, at which time fruit, foliage, and branches are covered with a sticky black slime. The extent of the injury depends upon the degree of infestation and upon the time of ripening of the fruit. Late varieties are damaged most by the mold-infested honeydew, as it shows worse upon fruit which ripens after the middle of August.

REMEDIAL MEASURES.

At the beginning of this investigation lime-sulphur was known to be ineffective and kerosene emulsion was considered unsatisfactory in the control of the terrapin scale. The so-called miscible oils (proprietary emulsifiable oils), however, were believed to be reasonably efficient when properly employed, though it was believed that there was more or less danger to the trees and fruit buds from their use.

For convenience in treatment the materials used in these experiments are considered in groups. In all 62 experiments were performed, most of them in the orchard of D. M. Wertz, at Mont Alto, Pa. The others were at Midvale, Pa., and at Washington, D. C.

A consideration of the life history of this scale shows that it can be attacked both in the larval and the adult stages. The adult stage, owing to its long duration and accessibility, obviously offers the more favorable opportunity for treatment. During the first season sprayings were made against both the larva and the adult.

OIL SPRAYS.

Experience shows that all oil sprays are most effective when applied as a fine mist and under strong pressure. All oils were applied with disk nozzles of the Vermorel type, having apertures of one-sixteenth inch. The oils noted in Table XXXVIII, all of which were applied in the spring after the buds had started to swell but before they had opened, proved to be inefficient. These oils were emulsified as follows:

Oil	2 gallons.
Soap (hard)	½ pound.
Hot water	1 gallon.

The soap was dissolved in the water and to this the oil was added. The whole was churned through a spray pump until no free oil remained. The emulsion was then diluted to the required strength and applied.

Figure 20 shows that portion of the Wertz orchard in which most of the experimental work was done. The orchard is in apples, interplanted mostly with Smock and Chair's Choice peaches. The trees were 11 years old in 1912 and very vigorous. At the beginning of the investigation these trees were grouped into 14 major plats, as shown in the figure. The check plats were used as such until a better method of checking was devised, when they were subplatted and sprayed. Most of the checking was done by scale counts from tagged branches upon special check trees left within the plats.

The rosin-oil emulsion was very efficient so far as killing scales was concerned. This oil dried rapidly, the trees soon appeared as if covered by a varnish, and the scales died almost at once. Unfortunately this oil gave very severe spray injury and some of the trees were so severely damaged that they required drastic pruning and stimulation to save them. While the spray injury could have been lowered by reducing the amount of oil, it was not thought advisable to continue the experiments.

The corn oil, which was also used as a 20 per cent emulsion, was equally good as a scale killer but formed a waxy scum over the branches and penetrated deeply into the tree, causing the death of many large limbs. These trees required drastic pruning and stimulation, but the injury was not so severe as in the case of the rosin oil. It was, however, too severe to justify its further use.

The gasoline, which was used as a 10 per cent emulsion, had a very low efficiency as a scale treatment but gave promise in other ways, as it readily dissolved the wax film which protects the scale from water, and it caused the scales to loosen temporarily from the bark. After the emulsion evaporated, however, the scales soon resumed their normal condition. This emulsion produced no spray injury.

MISCIBLE OILS (PROPRIETARY EMULSIFIABLE OILS).

In order to secure data for the better understanding of the factors that enter into the successful use of miscible oils the sprayings enumerated in Table XXXIX were made.

FIG. 20.—Map of the experimental plats in the D. M. Wertz orchard, Mont Alto, Pa. (Original.)
A, Apple trees. o, Peach trees.

TABLE XXXVIII.—*Data from plats sprayed with rosin-oil, corn-oil, and gasoline emulsions for the terrapin scale.*

Plat.	Experiment No.	Number of trees.	Age.	Degree of infestation.	Formula.	Application.	Scale count.					Spray injury.
							Date.	Total.	Dead.	Living.	Per cent dead.	
			Years.									
VII D	1	11	11	Heavy	Rosin oil, 20 per cent emulsion.	Apr. 11, 1912, dormant.	Apr. 15, 1912	100	98	2	98	Very severe.
							May 2, 1912	100	98	2	98	Do.
VII C	2	11	11	...do...	Corn oil, 20 per cent emulsion.	...do...	Apr. 20, 1912	100	98	2	98	Slight.
							Apr. 18, 1912	800	800	0	100	Do.
							May 5, 1912	100	98	2	98	Very severe.
Washington, D. C	3	1	2	...do...	Gasoline, 10 per cent emulsion.	Mar. 12, 1913, dormant.	Mar. 20, 1913	100	10	90	10	None.

TABLE XXXIX.—*Data from plats sprayed with miscible oils for the terrapin scale, seasons of 1912 and 1913.*

Plat.	Experiment.	Number of trees.	Age.	Degree of infestation.	Formula.	Application.	Scale count.						Spray injury.	Per cent dead in checks.	Final result.
							Date.	Total.	Dead.	Living.	Per cent parasitized.	Per cent dead.			
1912.			*Yrs.*												
North plat	1	40	11	Heavy	Miscible oil, 1 part; water, 18 parts.	Apr. 11, 1912	Apr. 15, 1912	200	180	20	0	90	None	0	Efficient.
South check, *d*	2	16	11	do	do	Dec. 23, 1912	Mar. 18, 1914	100	85	15	0	85	Injury severe.	0	Inefficient.
XI	3	100	12	Moderate	do	Mar. 29, 1913	Apr. 23, 1914	1,081	848	233	0	78.45	None	0	Do.
							May 2, 1914	1,725	1,062	663	0	61.57	do	0	
III *a*	4	17	11	Heavy	Miscible oil, 1 part; water, 16 parts.	Dec. 23, 1912	Mar. 18, 1914	100	85	15	0	85	Injury severe.	0	Do.
South check, *c*	5	28	11	do	Miscible oil, 1 part; water, 20 parts.	do	Mar. 18, 1913	100	70	30	0	70	Severe	0	Do.
South check, *b*	6	30	11	do	Miscible oil, 1 part; water, 24 parts.	do	do	246	133	113	0	46	Slight	0	Do.
South check, *a*	7	16	11	do	Miscible oil, 1 part; water, 30 parts.	do	do	100	15	85	0	15	do	0	Do.
1913.															
X *f*	8	17	12	do	Miscible oil, 1 part; water, 16 parts.	Mar. 29, 1913	Apr. 22, 1913	951	769	182	0	80.90	Very slight trace.	10	Efficient.
							May 2, 1913	1,072	981	91	0	91.52			
X *c*, *d*, *e*	9	55	12	do	Miscible oil, 1 part; water, 20 parts.	Mar. 28, 1913	Apr. 25, 1913	292	265	27	0	90.76	None	10	Do.
							May 19, 1913	1,033	928	105	0	89.84	do		
X *c*, *d*, and X *a*	[1] 10	75	12	do	Miscible oil, 1 part; gasoline, 1 part; water, 18 parts.	do	May 20, 1913	2,419	1,875	544	10	77.57	do	10	Do.
IX *a*, *b*, and X *d*	[1] 11	65	12	do	Miscible oil, 1 part; gasoline, 1 part; water, 20 parts.	do	May 21, 1913	2,432	1,967	465	10	80.28	do	10	Do.
VII *d* and VIII *b*	[1] 12	60	12	do	Miscible oil, 1 part; gasoline, 1 part; water, 28 parts.	do	do	1,120	936	184	10	83.57	do	10	Do.
VII *a*, *c*	13	45	12	do	Miscible oil, 1 part; gasoline, 1 part; water, 38 parts.	do	May 9, 1913	685	139	546	10	20.30	do	10	Inefficient.
Midvale, Pa	[1] 14	200	12	do	Miscible oil, 5 parts; gasoline, 3 parts; water, 92 parts.	Nov. 6, 1913	Mar. 31, 1914	1,784	1,142	642	0	64.01	Trace	55.01	Moderately efficient.

[1] The apparent discrepancy between the per cent dead and the final estimate is due to the falling of dead scales in the interval between spraying and counting.

In all cases the plats were first carefully inspected and typical branches were marked with tags which stated the condition of the scales and the nature of the infestation. About 10 per cent of the tagged trees were then left unsprayed and the results were taken by an individual examination of the scales upon the tagged branches. Before taking the scale count all winter killed and parasitized scales were removed from the branches, so that the count includes only scales that were alive and normal at the time the sprayings were made. The result of miscible-oil sprays became evident in a very few days after the application, when the dead scales began to drop. Because of the dropping of the scales it was found that counts should be made within one week after the application to show the true mortality. The result of delaying the count is well illustrated by a comparison of experiments 1 and 2. So far as the counts show these applications were equally effective, but in the second experiment there was an interval between the application and the count, and some of the dead scales had disappeared, thus making the mortality appear lower than it was. In comparing experiments 1 and 2, it appears that miscible oil at the strength of 1 gallon of oil to 18 gallons of water, when applied in the spring, is moderately effective against the scale, without producing injury to the trees, and that when applied in the fall it is nearly as effective against the scale, but produces severe injury to the trees.

Experiment 3 was made to determine the effect of using the regular lime-sulphur nozzles in applying miscible oil, and the plat was sprayed by the regular orchard force without oversight. Of the two counts made in experiment 3, the first represents the true mortality and the second shows only the condition of the scales present on May 2, when there were fewer dead scales than on April 23, due to their falling in the interval between the counts. The results in experiments 1 and 3 show clearly the necessity for using nozzles with smaller apertures and for making a more thorough application than is customary when applying dormant lime-sulphur sprays.

Experiments 4, 5, 6, and 7 show the effects of applying miscible oil in the winter, at a time when both the lecanium and the trees are dormant. When these applications were made the day was mild and calm, with the temperature well above freezing. A power outfit was used and the trees were sprayed until there was a slight dripping from the branches. The time between the date of applying these sprays and the date of making the scale count was rather too long to give the full mortality. The error, however, was small and was estimated at less than 5 per cent. These four experiments were all ineffective. Experiment 4 was accompanied by severe injury and experiments 5, 6, and 7 showed spray injury and failed to control the scale. It is therefore concluded that miscible oils are

not satisfactory when applied against the terrapin scale in the winter season.

In the spring of 1913 6 sprayings were made to test the efficiency of commercial miscible oils to which a wax solvent had been added. Accordingly experiments 8, 9, 10, 11, 12, and 13 were made and the sprays were applied in connection with the sprayings in experiments 1 to 7. It is to be noted that the spray used in experiment 8 was quite effective as a scale destroyer and that only a small amount of spray injury resulted. It serves, by contrast with experiment 4, to show that oils which are dangerous and ineffective when applied in winter may be applied with success in the spring. Particular attention is called to the effective work done by miscible oil when used at the rate of 1 gallon to 20 gallons of water in experiment 9. Where gasoline was added to the miscible oil there was a decided loosening of the scales, and many of the dead scales fell before the count was made, while comparatively few fell where miscible oil was used alone. This condition was noticed at the completion of the count, and comparisons were then made of the number of living scales in the plats having miscible oil only, in contrast with those having both miscible oil and gasoline, with the result that in all cases fewer living scales were found upon the twigs treated with the spray containing gasoline than upon those having miscible oil alone. It is therefore concluded, regardless of the count, that miscible oils are improved as a spray by the addition of gasoline emulsion.

Experiment 14 was made in Mr. A. Newcomer's orchard near Midvale, Pa., November 6, 1913, to determine the effect of a miscible oil and gasoline mixture when applied in the fall just after the leaves had fallen, and 15 trees were sprayed for comparison with the same percentage of miscible oil, but without gasoline. Unfortunately it was not possible to make a scale count until March 31, 1914, when many of the dead scales had fallen. Infested limbs upon the check trees were compared with similar branches on the trees in experiment 14, and these comparisons showed that the formula was more effective with gasoline than without it. The spray injury in this experiment was slight and the treatment was moderately efficient. All of the experiments made March 28 and 29, 1913, were finally rated as efficient, except No. 13, where the spray was deficient in oil. It is the author's belief that miscible oil—while not as desirable as linseed-oil emulsion, which is treated later—can be used with safety when applied just before the buds open, in dilutions of 1 gallon in 16 to 20 gallons of water. It is very effective, especially when the oil is mixed with one-half its volume of gasoline (emulsified). The natural mortality in the Newcomer orchard for the winter of 1913–14, as determined by a scale count from unsprayed trees, was 55.01 per cent.

COTTONSEED OIL.

The 10 experiments summarized in Table XL were made with cottonseed oil during 1912 and 1913. This oil was emulsified in all cases exactly as kerosene oil is emulsified in the preparation of kerosene emulsion. The sprays were applied in experiments 3, 4, 5, 6, and 7 with a hand sprayer and the applications were so thoroughly made that every scale was covered. The sprays in the other experiments were applied with a power sprayer.

TABLE XL.—*Experiments with cottonseed-oil emulsions against the terrapin scale.*

Plat.	Experiment No.	Trees.	Age.	Degree of infestation.	Formula.	Application.	Spray injury.	Final result.	Scale count.					Per cent dead in check.
									Date.	Total.	Dead.	Living.	Per cent parasitized.	Per cent dead.	
			Yrs.												
VIII *a*, east end.	1	11	11	Very heavy	Cottonseed oil, 20 per cent.	Apr. 11, 1912, dormant.	Slight..... Severe.....	Inefficient.....	Apr. 18, 1912 Apr. 20, 1912	800 200	800 188	0 12	0 0	100 94	0 0
I *d*, east end..	2	7	11	...do.....	Cottonseed oil, 18 per cent.	Nov. 9, 1912, dormant.	....do..... ....do.....	....do.....	Dec. 22, 1912 June 10, 1913	100 100	100 100	0 0	0 0	100 100	0 0
A, Washington, D. C.[1]	3	1	2	Heavy....	Cottonseed oil, 10 per cent.	Jan. 23, 1913, dormant.	Very severe.	.....do.....	Feb. 7, 1913	300	300	0	0	100	0
B, Washington, D. C.	4	1	2	...do.....	Cottonseed oil, 5 per cent.	Jan. 30, 1913, dormant.	None..... ....do.....	Very efficient.	Feb. 8, 1913 Apr. 24, 1913	200 200	190 190	10 10	0 0	95 95	0 0
C, Washington, D. C.	5	2	2	...do.....	Cottonseed oil, 2.5 per cent; gasoline, 2.5 per cent; water, 95 per cent.	Mar. 15, 1913, dormant.	....do..... ....do.....	....do.....	Mar. 20, 1913 Mar. 24, 1913	100 100	95 98	5 2	0 0	95 98	0 0
D, Washington, D. C.	6	1	2	...do.....	Cottonseed oil, 1.5 per cent; gasoline, 3.5 per cent; water, 95 per cent.	Mar. 15, 1913, dormant.	.....do.....	Inefficient.....	Apr. 24, 1913	100	40	60	0	40	0
E, Washington, D. C.	7	1	2	...do.....	Cottonseed oil, 10 per cent; gasoline, 5 per cent; water, 85 per cent.	Mar. 19, 1913, dormant.	Severe.....	.....do.....	.....do.....	218	215	3	0	98.63	0
VI, *a*, *b*, *c*[2]....	8	28	12	...do.....	Cottonseed oil, 2.5 per cent; gasoline, 2.5 per cent; water, 95 per cent.	Mar. 29, 1913, dormant.	None.....	Efficient.....	May 26, 1913	1,849	1,682	167	0	90.97	0
VI, *d*[2].....	9	16	12	...do.....	Cottonseed oil, 5 per cent.	Mar. 28, 1913, dormant.	....do..... Very slight..	Inefficient.....	Apr. 25, 1913 May 24, 1913	1,015 1,526	512 615	503 875	0 0	50.44 42.46	0 0
Midvale, Pa.[2].	10	90	12	...do.....	Cottonseed oil, 5 per cent; gasoline, 3 per cent; water, 92 per cent.	Nov. 5, 1913, dormant.	None..... ....do.....	Efficient.....	Dec. 4, 1913 Mar. 31, 1914	100 100	85 90	15 10	0 0	85 90	21

[1] This tree died from spray injury. [2] These counts represent less than the maximum efficiency of the spray, owing to the dropping of killed scales before the date of counting.

TABLE XLI.—*Experiments with raw linseed-oil emulsions against the terrapin scale.*

Plat.	Experiment No.	Number of trees.	Age.	Degree of infestation.	Formula.	Application.	Scale count.						Spray injury.	Final result.
							Date.	Total.	Dead.	Living.	Parisitized.	Per cent dead.	Per cent dead in check	
VIII *b*.....	1	11	*Yrs.* 11	Heavy....	Linseed oil, 20 per cent emulsion.	Apr. 5, 1912, dormant.	Apr. 20, 1912	123	115	8	0	93.49	0	Moderately severe.	
							June 28, 1912	100	98	2	0	98	0		
							July 17, 1912	100	98	2	0	98	0	Severe..	Inefficient.
Washington, D. C.	2	1	2	....do.....	Linseed oil, 10 per cent emulsion.	Mar. 19, 1913, dormant.	Mar. 24, 1913	100	100	0	0	100	0	None....	Very efficient.
V *d*.....	3	11	12	....do.....	Linseed oil, 5 per cent emulsion.	Mar. 28, 1913, dormant.	Apr. 25, 1913	722	601	121	0	83.24	0	...do.....	Moderately efficient.
V *b, c*.....	4	22	12	....do.....	Linseed oil, 2.5 per cent; gasoline, 2.5 per cent.	Mar. 28, 1913, dormant.	May 28, 1913	889	728	161	0	81.89	0	...do.....	Efficient.
Midvale, Pa..	5	200	12	....do.....	Linseed oil, 5 per cent; gasoline, 3 per cent.	Nov. 5, 1913	Mar. 30, 1914	1,489	1,489	0	0	100	54.74	...do.....	Very efficient.

TABLE XLII.—*Data from plats sprayed with mixed oils for the terrapin scale.*

Plat.	Experiment No.	Trees.	Age.	Degree of infestation.	Formula.	Application.	Scale count.						Spray injury.	Final results.
							Date.	Total.	Dead.	Living.	Per cent parasitized.	Per cent dead.	Per cent dead in check.	
III *d*.....	1	22	*Yrs.* 12	Heavy....	Raw linseed oil $2\frac{1}{2}$ parts, cottonseed oil $2\frac{1}{2}$ parts, water 95 parts.	Mar. 28, 1913	May 29	1,840	1,334	506	0	72.83	0	None....	Inefficient.
IV *a*.....	2	11	12	.....do.....	Raw linseed oil $1\frac{1}{2}$ parts, cottonseed oil $1\frac{1}{1}$ parts, gasoline $2\frac{1}{2}$ parts, water 95 parts.	.....do.....	May 28	1,639	874	765	0	53.33	0	...do.....	Do.

TABLE XLIII.—*Experiments against the terrapin scale with sprays containing nicotine as the active ingredient, Mont Alto, Pa.*

Plat.	Experiment No.	Trees.	Age.	Degree of infestation.	Formula.	Application.	Scale count.							
							Date.	Total.	Dead.	Living.	Per cent parasitized.	Per cent dead.	Per cent dead in check.	Spray injury.	Final results.
			Yrs.												
IV	1	73	11	Heavy	Nicotine sulphate 1 part, 3 per cent kerosene emulsion 400 parts.	Apr. 5, 1912, dormant.	Apr. 20	175	25	150	0	14.3	0	None	Inefficient.
VI	2	93	11	do	Nicotine sulphate 1 part, 10 per cent lime-sulphur solution 400 parts.	do	do	186	24	162	0	13	0	do	Do.
VII	3	88	11	do	Nicotine sulphate 1 part, 1.6 per cent miscible-oil emulsion 400 parts.	do	do	100	30	70	0	30	0	do	Do.
V	4	90	11	do	Tobacco extract 1 part, 3 per cent kerosene emulsion 20 parts.	do	May 24	200	23	177	0	11.5	0	do	Do.
North check	5	34	11	do	Nicotine sulphate 1 part, 3 per cent kerosene emulsion 400 parts.	Aug. 6, 1912, twigward migration.	Aug. 16	300	55	245	0	18.3	0	do	Do.
II *c, d*	6	40	11	do	Nicotine sulphate 1 part, 3 per cent kerosene emulsion 400 parts.	Aug. 22, 1912, young females upon the twigs.	Sept. 16	100	50	50	0	50	0	Severe	Do.
II *a*	7	12	11	do	Tobacco extract 1 part, 3 per cent miscible-oil emulsion 20 parts.	do	Sept. 13	100	60	40	0	60	0	do	Do.
I *a, b, c*	8	40	11	do	Nicotine sulphate 1 part, 6 per cent kerosene emulsion 400 parts.	Nov. 9, 1912, dormant.	Dec. 22	100	8	82	0	8	0	None	Do.

TABLE XLIV.—*Coating sprays against the terrapin scale applied in 1912.*

Plat.	Experiment No.	Trees.	Age.	Degree of infestation.	Formula.	Application.	Scale count.						Per cent dead in check.	Spray injury.	Final results.
							Date.	Total.	Dead.	Living.	Per cent parasitized.	Per cent dead.			
			Yrs.												
V	1	90	11	Heavy	Self-boiled lime sulphur, 8-8-50.	May 24, 1912 (scales mature).	Sept. 3	200	23	177	10	11.5	10	None	Inefficient.
IX	2	77	11	do	do	June 17, 1912 (leafward migration).	July 8	100	15	85	0	15	0	do	Do.
X	3	105	11	do	do	June 17, 1912	July 8	100	0	100	0	0	0	do	Do.
						July 9, 1912	Sept. 13	800	761	39	0	96.3	90	do	Do.
XI	4	77	11	do	do	June 17, 1912	July 8	100	.....	100	0	0	0	do	Do.
						July 8, 1912									
						Aug. 6, 1912	Sept. 5	100	90	10	0	90	90	None	Do.
VII *d*	5	24	11	do	Self-boiled lime sulphur 8-8-50, and 2½ gallons of tobacco extract.	July 9, 1912 (leaf-attached larvæ).	do	100	90	10	15	90	90	do	Do.
VII *d*	6	10	11	do	Self-boiled lime sulphur 8-8-50, plus 1 gallon tobacco extract.	July 9, 1912	do	100	90	10	15	90	90	do	Do.
South check *a*	7	21	11	do	Stone lime 12 pounds, sulphur 3 pounds, water 50 gallons.	Aug. 6, 1912 (twigward migration).	Aug. 16	100	25	75	10	25	10	do	Do.
III *b*, west end	8	12	11	do	Paris white 15 pounds, glucose 3 gallons, water 47 gallons.	Aug. 5, 1912	Sept. 30	100	10	90	10	10	10	do	Do.
III *a*, west end	9	12	11	do	Stone lime 20 pounds, casein 5 pounds, water 50 gallons.	Aug. 6, 1912	do	200	22	178	10	11	10	do	Do.
III *a*, east end	10	7	11	do	Pulverized China clay 15 pounds, water 50 gallons.	do	do	100	10	90	10	10	10	do	Do.

TABLE XLV.—*Experiments against the terrapin scale with coating sprays to which flour had been added, season of 1913.*

Experiment No.	Trees.	Age.	Degree of infestation.	Formula.	Application.	Scale count.					Per cent dead in check.	Spray injury.	Final results.
						Date.	Total.	Dead.	Living.	Per cent parasitized.	Per cent dead.			
		Years.											
1	12	12	Heavy	Flour 10 pounds, stone lime 15 pounds, sulphur 20 pounds, water 50 gallons.	June 12, 1913	July 8	1,007	948	59	5	94.1	21	None	Very efficient.
2	12	12	...do	...do	June 12, 1913	July 7	1,152	1,141	11	5	99	21	...do	Do.
					July 10, 1913	Aug. 4	100	99	1	5	99	21	...do	
3	12	12	...do	...do	July 10, 1913	Oct. 14	100	26	74	5	26	21	...do	Inefficient.
4	3	12	...do	...do	July 29, 1913	Aug. 6	100	15	85	0	15	0	...do	Do.
5	8	12	...do	Flour 10 pounds, stone lime 15 pounds, sulphur 20 pounds nicotine sulphate 1 pint, water 50 gallons.	June 17, 1913	June 28	2,306	2,093	23	5	90.71	21	...do	Efficient.
6	16	12	...do	...do	June 17, 1913 July 10, 1913	Aug. 8	100	90	10	5	90	21	...do	Do.
7	6	12	...do	...do	July 10, 1913	...do	100	26	74	5	26	21	...do	Inefficient.
8	1	12	...do	...do	July 29, 1913	Aug. 6 Aug. 9	100	26	74	5	26	21	...do	Do.
9	5	12	...do	Flour 10 pounds, water 50 gallons.	July 10, 1913	Aug. 8	100	0	100	0	0	0	...do	Do.
10	5	12	...do	Flour 10 pounds, stone lime 15 pounds, sulphur 20 pounds, water 50 gallons.	July 10, 1913, twigward migration.	...do	100	0	100	0	0	0	...do	Do.

The spray used in experiment 1, which was made just before the flower buds burst, was very effective as an insecticide. Every scale that was covered with the spray solution was killed. Of 1,000 scales examined only 1.2 per cent were alive, and these were protected in various ways from the spray and were not completely drenched. The spray injury was severe, however, owing to the excessive amount of oil.

Experiment 2 was made late in the fall with 2 per cent less oil. This spray was very efficient against the scale, but the injury was more pronounced than in experiment 1. The trees used in both experiments required severe pruning and a liberal application of sodium nitrate to restore them to their original vigor.

Experiment 3 was made at Washington, D. C., to determine the effect of this oil upon young trees. A vigorous 2-year-old tree was thoroughly sprayed with a hand sprayer until all the scales were wet with a 10 per cent emulsion of the oil. All the scales upon this tree were destroyed, but the spray injury was so severe that the tree died. It is worthy of note that this was the only tree killed with oil during the two seasons' work. The increased tolerance of the older trees to oil seems to be due entirely to the protection afforded by their corky bark.

Experiment 4 was also made at Washington. It shows that cottonseed oil in a 5 per cent emulsion can be applied effectively and safely to 2-year-old trees in mild winter weather. This formula, however, does not contain enough of oil to make it effective against the terrapin scale when applied on old trees, as is clearly shown in experiment 9.

Experiment 5 was also made at Washington, D. C. Two heavily infested 2-year-old trees were sprayed with a 5 per cent emulsion of equal parts of cottonseed oil and gasoline. A hand sprayer was used and all the scales were thoroughly wetted with the spray. Nine days after the application 98 per cent of the scales were dead and no spray injury developed during the season. This spray was also effective against scale upon old peach trees, as is shown in experiment 8.

In experiment 6 the amount of oil was reduced to 1.5 per cent and the gasoline was increased to 3.5 per cent. The application was made in the same manner and at the same time as in experiments 3, 4, and 5, but it was ineffective, owing to the small percentage of oil. The high percentage of gasoline increased the wax-solvent power of the solution and its narcotic power, but did not directly contribute to its killing power.

Experiment 7, in which 10 per cent cottonseed oil and 5 per cent gasoline was used, gave practically the same results as 10 per cent cottonseed oil when used alone. Since experiment 7 shows less

spray injury than experiment 3, it is evident that the gasoline did not tend to increase the spray injury. This experiment, in connection with experiment 3, shows that a 10 per cent emulsion of the oil, even when used at the most favorable season, is too strong for 2-year-old trees whether used with or without gasoline. The formula in experiment 7, while containing more oil than is required for killing scale upon young trees, would undoubtedly be very effective when used upon old trees, but owing to the effective results obtained with 2½ per cent of this oil in experiments 5 and 8, it was not thought advisable to experiment further with the 10 per cent emulsion.

In experiment 8 an emulsion containing 2½ per cent of cottonseed oil and 2½ per cent of gasoline was applied to 28 vigorous 12-year-old trees at Mont Alto, March 29, 1913, with very satisfactory results. The interval between the application of this spray and the time of making the scale count was too long to show the maximum efficiency of the spray, nevertheless the mortality as shown is above 90 per cent and there was no spray injury. Observations made upon the trees used in this experiment show that the oil content could have been considerably increased without injury to the trees.

Experiment 9, in which a 5 per cent emulsion of cottonseed oil was carefully sprayed upon 16 trees at Mont Alto, Pa., gave unsatisfactory results. The mortality was about 50 per cent and the spray injury was negligible. The oil in this case seemed to lack penetration and spreading power.

A comparison of the data in this experiment with that in experiments 5, 8, and 10 shows that a 5 per cent emulsion of this oil is satisfactory only when used with gasoline. Experiment 10 was the last one performed with cottonseed oil. An extensive spraying was made to test the efficiency of the gasoline and cottonseed-oil emulsion when applied in the fall. This experiment was successful and showed that the terrapin scale can be attacked in the fall with satisfactory results. Cottonseed oil, however, gives its best results when applied in the spring. It is possible to increase the percentage of cottonseed oil in this formula up to as high as 7 per cent without noticeable injury to the trees. This increase in oil, however, adds to the cost of the spray without greatly increasing its efficiency, except for use on old trees with very rough bark. In this case it may be found of advantage to use 7 per cent of the oil.

LINSEED OIL.

Five experiments against the terrapin scale were made with raw linseed oil. The essential facts established in these experiments are shown in Table XLI.

Experiment 1 was made at Mont Alto, Pa., upon vigorous 11-year-old trees that were nearly ready to burst into bloom. The same

power outfit was used as in applying the cottonseed-oil sprays. The oil was emulsified in the same way as kerosene in making kerosene emulsion. This oil at 20 per cent gave an efficiency of from 93 to 100 per cent, but the injury to the trees was severe. It did far less injury, however, than any other of the oils used at this strength. This experiment shows that raw linseed oil was a promising oil and that it should be used at a much decreased strength.

Experiment 2 was performed on March 19, 1913, by spraying a vigorous 2-year-old tree at Washington, D. C., with a 10 per cent emulsion of raw linseed oil. This spray was applied very thoroughly with a hand sprayer at the time the buds were swelling. Every scale upon this tree was killed and there was no spray injury. The experiment shows that it is feasible to apply a 10 per cent emulsion to 2-year-old trees in the spring without injury.

Experiment 3 demonstrated that a 5 per cent emulsion of raw linseed oil will destroy more than 80 per cent of the scales upon 12-year-old trees, provided the application is made in the spring before the buds open. In experiment 4 the formula used differs from the one used in No. 3 in that gasoline was substituted for one-half of the oil. The scale count gives nearly the same efficiency for this experiment as for the preceding one. This experiment shows clearly that gasoline increases the efficiency of the spray. Experiment 5 was made by spraying 200 moderately vigorous 12-year-old peach trees at Midvale, Pa., November 5, 1913, at which date the trees had just finished shedding their leaves. An emulsion containing 5 per cent raw linseed oil and 3 per cent gasoline was applied with a power sprayer, furnishing 175 to 200 pounds pressure, and equipped with angle nozzles having apertures of one-sixteenth inch. The efficiency upon well-sprayed branches was 100 per cent and there was no spray injury.

Experiments 4 and 5 show that an emulsion containing 5 per cent raw linseed oil and 3 per cent gasoline will effectively control the terrapin scale without injury to the trees. While experiment 5 shows that linseed oil gives good results in the fall, the author recommends that this oil be applied in the spring just before the buds open.

Cost of Linseed Oil.

At the date of writing this paragraph linseed oil sold in Washington, D. C., for 50 cents per gallon in barrel lots, and gasoline at 13 cents per gallon. The cost of this spray, exclusive of the labor of making it, would be about 3 cents per gallon.

5 gallons raw linseed oil, at 50 cents	$2.50
3 gallons gasoline, at 13 cents	.39
2 pounds laundry soap, at 5 cents	.10
92 gallons water	
100 gallons	2.99

It requires from 1½ to 2½ gallons of this emulsion thoroughly to spray a vigorous 12-year-old tree. The average tree of this age requires about 2 gallons, while a 2-year-old tree requires from a pint to a quart. It appears that from these figures the spray material will cost from 1 cent to 8 cents per tree.

A single application of this spray, if carefully made, will control the terrapin scale. It has been found that the best way of preparing this spray is by mixing 5 gallons of raw linseed oil and 3 gallons of gasoline and then adding 2 pounds of soap dissolved in 4 gallons of hot water. The whole is churned for 5 minutes through a spray pump, then diluted to double its volume and churned again for 1 minute, after which it should be diluted to 100 gallons, when it is ready to use.

MIXED OILS.

Two experiments were performed in 1913 with emulsions of mixed oils. These emulsions were made and applied in exactly the same way as the linseed-oil emulsions.

Table XLII shows the chief details, and the results for the mixed-oil emulsions. These experiments, when compared with experiments 3 and 4 of Table XLI, show that these mixed oils were less efficient than raw linseed oil and that there is no advantage in mixing them.

NICOTINE.

Eight experiments were made with nicotine compounds. These sprays were applied partly with a barrel sprayer and partly with a power sprayer, but the same set of disk nozzles was used in all cases. The chief details and the results of these experiments are recorded in Table XLIII.

When reference is made to nicotine sulphate, the commercial article containing 40 per cent of nicotine is intended; likewise references to tobacco extract refer to preparations containing 2.7 per cent of nicotine, or its equivalent.

Experiments 5 and 6 of Table XLIV and experiments 5, 6, 7, and 8 of Table XLV are to be considered in connection with Table XLIII. Of these 14 experiments, 5 were directed against the hibernating scales (4 of these in the spring and 1 in the fall); 5 against the leaf-attached larvæ, 2 against the females while making the twigward migration, and 2 against the young females while making their maximum growth. These experiments were all negative and showed that nicotine is ineffective against the terrapin scale.

COATING SPRAYS.

A number of experiments were performed in 1912 with coating sprays, to determine the feasibility of smothering the scale. The chief details and the results of these experiments are recorded in

Table XLIV. The first 4 experiments were made with self-boiled lime-sulphur, 8–8–50, and were applied with coarse nozzles at a pressure of 100 pounds.

In experiment 1 the application was made May 24, when 95 per cent of the overwintered scales were mature. This spraying was both extensive and thorough, but was inefficient against the mature females and failed to control the sooty molds. Experiment 2 was directed against the larvæ during the beginning of the leafward migration, but gave an efficiency of only 15 per cent and also failed to control sooty molds.

In experiment 3 two applications were made, the first at the beginning of the leafward migration and the last when 95 per cent of the larvæ were upon the leaves. Both sprayings were ineffective and the small mortality (6.3 per cent) came entirely from the first application.

In experiment 4, 3 applications were made, when the leafward migration started, when 95 per cent were upon the leaves, and just before the twigward migration. These applications were also ineffective, and the mortality was no greater than in the case of experiment 1. The fungus was partly controlled, but the fruit was coated with lime to such an extent that the general effect was injurious rather than beneficial.

In experiments 5 and 6 tobacco extract was added to the self-boiled lime-sulphur, and the applications were made when 95 per cent of the larvæ were upon the leaves. These experiments gave no better results than the preceding ones and showed that tobacco extract is inefficient, at the strength used, when applied against the larvæ when they are upon the leaves.

In experiment 7 self-boiled lime-sulphur was modified to increase the thickness of the coating, and was directed against the young females. The branches of the young twigs were coated just before the females started their twigward migration. This experiment was ineffective.

Experiment 8 was made to test the smothering properties of Paris white and glucose. The application was made with a barrel pump, just before the females started migrating to the twigs. The spray was ineffective.

In experiment 9 a thick whitewash, to which casein had been added, was applied just before the young females started the twigward migration. The limbs were heavily coated, but the scales were not killed.

In experiment 10 pulverized china clay was used. It proved to be a poor coating material and was inefficient. Considered as a whole the experiments in Table XLIV indicate that self-boiled lime-sulphur is ineffective when applied at the time of the twigward migration,

both against the scale and the sooty molds. They also indicate that the other substances tested are ineffective against the terrapin scale.

The experiments with coating sprays performed in 1912 were failures, so far as controlling the terrapin scale was concerned, but they were valuable in showing that sulphur was the active component of self-boiled lime-sulphur and that its efficiency could be improved by increasing its spreading and sticking powers. It was evident also that sulphur was ineffective against the mature females.

COATING SPRAYS WITH FLOUR ADDED.

In 1913 experiments were made to perfect a coating spray by adding a spreader and sticker to self-boiled lime-sulphur and by increasing the sulphur content. The chief details and the results of these experiments are recorded in Table XLV.

In these experiments the flour was first made into a thin batter with cold water and then cooked to form a paste. The other ingredients were combined exactly as in making self-boiled lime-sulphur, after which the flour paste was added.

In the first four experiments the same spray was used. Experiment 1 was directed against the larvæ during the leafward migration and was very successful. Experiment 2 was directed both against leafward migrants and against the larvæ upon the leaves. It shows high efficiency, which is, however, entirely due to the first spraying, as is shown by the negative results in experiment 3.

Experiments 5, 6, 7, and 8 were performed with the same formula used in the preceding experiments, except that 1 pint of 40 per cent nicotine sulphate was added. The results from these experiments show that the nicotine adds nothing to the efficiency of the spray.

Experiment 9 was made with flour paste and shows that flour acts only as a spreader and adhesive and not as a killing agent.

Experiment 10 was made with modified self-boiled lime-sulphur to which flour paste was added, and was directed against the larvæ after they were well established upon the leaves. The spray was ineffective, as were all other applications made against the leaf-attached larvæ.

From these experiments it appears that the terrapin scale can be controlled by a coating spray applied against the larvæ during the leafward migration and that these sprays are inefficient at other times. Coating sprays are more difficult to apply than the oil sprays and require a first-class sprayer with a powerful agitator and plenty of pressure. Coarse-angle nozzles should be used and the underside of the leaves should be thoroughly drenched, and the spray must be applied just before the young emerge. The time for applying this spray, which is immediately after the appearance of young under the

scales, can best be determined by displacing a number of scales daily during the early part of June. In the region of Mont Alto, Pa., the young will appear under the scales about June 12. For this coating spray use the following formula:

	Pounds.
Stone lime	15
Sulphur	20
Flour	10
Water to make 50 gallons.	

The lime and sulphur are combined exactly as in making self-boiled lime-sulphur. The flour is made into a thin batter with cold water and cooked to a paste. It is then added to the lime-sulphur, and the whole should then be diluted to 50 gallons, when it is ready for use. Particular care must be taken to get a batter free from lumps; if this is done, and the spray is strained through a sieve, there will be no trouble in passing it through the nozzles. This spray when properly applied will kill from 94 to 100 per cent of the larvæ. It is effective only against the leafward migrating larvæ and is useless if applied after the larvæ have attached to the leaves.

SUMMARY.

SUMMARY OF LIFE HISTORY.

The female of the terrapin scale reaches maturity about the 1st of June and gives birth to living young soon afterwards. These are retained for a period of from 1 to 3 days in the brood chamber, which is a dome-shaped cavity beneath the scale. They then emerge and migrate at once to the underside of the leaves, where they settle, mostly along the midrib and the larger veins. The first instar, which lasts about 18 days, is vegetative and the larvæ show no sexual differentiation, but during the second instar, which also lasts about 18 days, sexual differentiation is very pronounced. At the end of this instar the female is very flat and circular, while the male, which is flat and decidedly oval, is protected by a conspicuous waxy structure called the puparium. After the second instar the sexes follow entirely different lines of development.

The female remains for 1 day upon the leaves after entering the third instar, which is the final instar for this sex. During this day it secretes a thin wax scale, which protects it during the twigward migration. At the beginning of this migration the female larvæ abandon the leaves and pass to the basal part of the new growth, where they make their final attachment within the area of greatest illumination. They then commence a period of rapid growth, during the first 11 days of which they develop their mating color, which is a conspicuous red band upon the middorsal line. At the time the dorsal band is completed the male migrates to the leaves, mates, and

dies. The female after mating starts a rapid growth during which the mating colors and the larval characters are lost and during which vast quantities of honeydew are deposited. By the end of the twentieth day upon the twig the female has assumed all the adult characters. After this, growth gradually slackens until the cold of the approaching winter forces the scale into hibernation. In the spring growth is resumed. Maturity is reached early in June and the scale dies early in July, after having lived about 13 months.

The male, which makes the second molt and passes all of its remaining instars, except the last day of the imago, under the protection of the puparium, loses its mouth-parts at this time and lives during the remainder of its life upon nourishment taken in the first two instars. The third or prepupal instar lasts about 2 days and is a period of rapid metamorphosis, in which the larval organs are replaced by the adult structures. In the fourth or pupal instar, which lasts for about 8 days, the adult organs reach their full development. At the fourth and final molt the imago escapes from the pupal case, but remains for about 2 days under the puparium before emerging, when it migrates at once to the twigs, copulates, and then dies, after having lived about 49 days.

SUMMARY OF REMEDIAL MEASURES.

An endeavor was made to prevent the soot injury which is the main cause of complaint from orchardists against this scale. During the first season one series of sprayings was made to control it in the presence of the living scale, and another series was made to control it by destroying the scale. It was found impracticable to control the "soot" directly. Accordingly in the second season all sprayings were made against the scale. Seven groups of materials were tested, the first of which contained corn oil, rosin oil, and gasoline. Of these, the two former were good treatments, but were very injurious to the trees. The latter was inefficient but gave promise as a wax solvent and penetrant.

Miscible Oils.

The second group contained miscible oils. Nine experiments were made with miscible oil, including 5 with miscible oil and gasoline, and 2 with miscible oil and nicotine.

In the first case it was evident that miscible oil was injurious when used in the winter at effective strengths, but that it could be used without injury if applied in the spring between the swelling and the bursting of the fruit buds. It was also evident that healthy 11-year-old trees could be sprayed for three consecutive seasons with miscible oil 1 to 18 without injury to the trees, and that the scale could be controlled by two seasons' spraying with this oil.

In the second case it was evident that combining gasoline emulsion and miscible oil added to the efficiency of the oil. The greatest efficiency was obtained when 5 parts of miscible oil were added to 3 parts of gasoline (emulsified) and 92 parts of water. In the third case it was evident that adding nicotine did not increase the efficiency of miscible oil.

Cottonseed Oil.

The third group consisted of 10 experiments made with cottonseed oil. This was a promising oil and both its penetration and wax-solvent powers were greatly increased by the addition of gasoline. The highest efficiency was obtained by using an emulsion containing

Cottonseed oil	5 gallons.
Gasoline	3 gallons.
Soap	2 pounds.
Water	92 gallons.

combined as indicated on page 67. This oil proved nearly as effective as linseed oil.

Linseed Oil.

The fourth group consists of 5 experiments made with raw linseed oil. It was soon evident that this oil was promising. It was very efficient when used alone as a 10 per cent emulsion, but it gave even better results when combined with gasoline. The gasoline component increases the fluidity of the oil, dissolves the protecting wax film, and tends to asphyxiate the scales. After the emulsion has penetrated to the underside of the scale this component evaporates, while the other component, after smothering the scale, becomes inert. In this respect it is superior to the oils ordinarily used against this scale. The best results are obtained by using an emulsion made up as follows:

Raw linseed oil	5 gallons.
Gasoline	3 gallons.
Laundry soap [1]	2 pounds.
Water	92 gallons.

When made as indicated on page 82, this emulsion applied in the spring before the buds burst will control the terrapin scale at a single application and at a cost for material of from 1 to 8 cents per tree. This was found to be the most effective treatment of any of the remedies tried against this insect.

Mixed Oils.

Group 5 contains only two experiments. They show conclusively that there is no advantage in mixing linseed and cottonseed oils.

[1] This is the minimum amount; more may be required if the soap is mild.

Nicotine.

In group 6 the efficiency of nicotine was tested in 14 experiments. Both the commercial sulphate and the aqueous solution were tested. This substance proved inefficient in all cases.

Coating Sprays.

In group 7 various coating sprays were tested. Twenty experiments were made. They were intended for the control of both the sooty fungus and the terrapin scale, but were ineffective against the "soot" in all cases where the insect was not killed.

From these experiments it is evident that the period in the life history of this insect when it can be most readily controlled by a coating spray is during the leafward migration. It is also evident that sulphur is the efficient component in the coating sprays, and that the ordinary self-boiled lime-sulphur lacked the spreading and adhesive properties necessary to make it an efficient coating spray. The modified formula given under "Recommendations" (second formula, below) was accordingly devised.

RECOMMENDATIONS FOR CONTROL.

Spray in the spring before the buds burst, with the following emulsion (see page 82):

Raw linseed oil	5 gallons.
Gasoline	3 gallons.
Soap	2 pounds.
Water	92 gallons.

If the foregoing formula is not used, spray with proprietary miscible oils, containing not less than 75 per cent mineral oil, at the rate of 1 part to 16 to 20 parts of water. Applications of this formula should likewise be made in the spring during the period between the swelling and the opening of the buds. (See pp. 68–73.)

To protect a crop after the trees are in foliage, spray just before the leafward migration (see pp. 19–24) with the following formula (p. 85):

Flour (in paste)	10 pounds.
Stone lime	15 pounds.
Sulphur	20 pounds.
Water to make	50 gallons.

This should be applied at the time the young appear in the brood chambers, but before they have emerged. This time can be best determined by making a daily examination of infested twigs. Since the young are not destroyed after they have attached, only one thorough application is advisable. This treatment, owing to the limited time for its application, is not as practicable as the dormant sprayings and should be used only in emergencies. This spray does not seriously coat the fruit.

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